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ABSTRACT

This review covers approximately 300 studies, including journal articles, dissertations, and papers presented at conferences. The studies are organized under these major headings: status surveys; scientific reasoning; elementary school science (student achievement, student conceptions/misconceptions, student curiosity/attitudes, teaching methods, and technology/microcomputers); junior high science (student achievement, student attitudes, student concepts/misconceptions, teaching methods, and others); high school general science (student characteristics, classroom behaviors, and curriculum); high school physical science (teaching methods, testing methods, and technology/microcomputers); high school earth science (student characteristics, teaching methods, and curriculum); high school biology (student characteristics, teaching methods, and others); high school chemistry (student conceptions/misconceptions, testing, and others); high school physics (student conceptions/misconceptions, student attitudes, teaching methods, curriculum, and testing); university geology; university biology (student characteristics, textbooks, problem-solving, curriculum, and others); university chemistry (teaching methods, curriculum, textbooks, and others); university physics (student conceptions/misconceptions, problem-solving, and others); informal science education; specific interests; preservice teacher education; inservice teacher education; and research methodology (clinical interviews, time-series, aptitude-treatment interaction, qualitative research, meta-analyses, and attitude measures). A bibliography of studies reviewed is included. (JN)

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A SUMMARY OF RESEARCH IN SCIENCE EDUCATION -- 1984

THE ERIC SCIENCE, MATHEMATICS AND ENVIRONMENTAL EDUCATION CLEARINGHOUSE
in cooperation with
Center for Science and Mathematics Education
The Ohio State University

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Foreword

Research Reviews are being issued to analyze and synthesize research related to the teaching and learning of science completed during a one year period of time. These reviews are developed in cooperation with the National Association for Research in Science Teaching. Appointed NARST committees work with staff of the ERIC Clearinghouse for Science, Mathematics, and Environmental Education to evaluate, review, analyze, and report research results. It is hoped that these reviews will provide research information for development personnel, ideas for future research, and an indication of trends in research in science education.

Readers' comments and suggestions for the series are invited.

Stanley L. Helgeson
Patricia E. Blosser
ERIC/SMEAC

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Contents

Introduction 1

Status Surveys 3

Scientific Reasoning 9

Elementary School Science 23

Junior High Science 32

High School General Science 43

High School Physical Science 46

High School Earth Science 48

High School Biology 50

High School Chemistry 63

High School Physics 70

University Geology 73

University Biology 75

University Chemistry 83

University Physics 87

Informal Science Education 92

Specific Interests 94

Preservice Teacher Education 106

Inservice Teacher Education 112

Research Methodology 121

References 125

Additional References 154

A Summary of Research in Science Education — 1984

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Introduction

A serious problem faced by those of us concerned with the improvement of science education is the considerable gap which exists between research and practice. For example, research study after research study during the past several years has found hands-on, activity-based "inquiry" instruction far superior to lecture-based, fact-laden "expository" instruction for practically every positive benefit to students imaginable. The work of Shymansky (251) provides perhaps the best illustration of this point. Shymansky analyzed the results of 302 studies comparing inquiry and expository instruction and found inquiry to be superior across all measures of performance with the effect sizes most marked for inquiry programs based upon the work of the Biological Sciences Curriculum Study (BSCS). The average BSCS student was found to outscore 84 percent of expository course students on attitude measures, 81 percent on process skills, 77 percent on analytic skills, and 72 percent on achievement. Yet it is widely known among researchers that most teachers today, not only are teaching using the less effective expository methods but they are even unaware of the vast body of research that has shown their methods to be less effective.

Surely there are many reasons for this gap between research and practice, most of which cannot be addressed in a literature review. Yet there is perhaps one thing that can be done in a review. Allow us to generate the hypothesis that one reason research results are seldom put into practice is that researchers do not present their results in a way that is easily accessible to the practitioner. Take, for example, the recent study by Ronning, McCurdy and Ballinger (238) entitled "Individual Differences: A Third Component in Problem-Solving Instruction." Here is a study of considerable interest. Any researcher who reads this study can easily imagine its general relevance to science teaching. Yet which teachers are going to read this, high school physics teachers? high school chemistry teachers? junior high science teachers? college biology teachers? These are the practitioners, yet nothing in the title, and little in the introduction, alerts the reader that the study is most relevant to the junior high general science teacher. This is perhaps as it should be as the study is most certainly theory-based, and has implications well beyond junior high school science. Yet the point is that our methods of reporting results often fail to consider the practitioners which, like it or not, align themselves with specific disciplines at specific grade levels.

Thus, in hopes of making the present review of 1984 research more easily accessible to the practitioner (and no doubt less accessible to the researcher), we have decided to organize the review around specific disciplines at specific grade levels. A glance through the table of contents will reveal this clearly. You will note only a few exceptions to this rule. Only topics that so obviously cut across ages and disciplines (i.e., the acquisition and deployment of scientific reasoning abilities, and females in science) and topics without specific disciplines or age levels (e.g., energy education) have been given separate headings. Even though we realize that this organization will present some obstacles to the theory-based researcher, we trust that he or she will be more motivated and able to overcome these obstacles and synthesize results from disparate areas than would be the practitioner. If so, our review may be of some value to both concerned parties.

The reader should be aware that, aside from the organization of the research summary, we have made no attempt to be original. In many instances we found the author's original abstracts to be very adequate for our needs and felt little need to improve upon them. For that reason many of the abstracts appear nearly in the authors' own words. Therefore, if for some reason you wish to cite research results that are reported, please make citations of the original work and not this summary.

We chose not to cite every research effort reported during 1984 simply because, in our view, they were not all worth reporting. This is, however, not to say that we found the literature to be generally weak as some past reviewers apparently have implied. Quite the contrary, we found most research to be informative and well conducted

and reported. In our view, the current problems in science education do not stem from our inability to discover what should be taking place in the classroom. Rather, the problems stem from our inability to put our knowledge into practice.

Status Surveys

Introduction

A total of 20 studies are reviewed in this category. Four studies dealt with student achievement, as reported in the Second International Science Study (SISS) and the National Assessment of Educational Progress (NAEP). Four studies dealt with the exemplary programs and related variables. A third subcategory, regional studies, contains four reports involving data from specific states or regions of the country. Seven studies are reported related to teacher shortages; one study reports on the development of computer software.

Student Achievement

Kreiger (149) reported that the preliminary analysis of the Second International Science Study (SISS), given in 1983, show that the overall science scores for fifth and ninth graders (N=5000) have improved since the last test in 1970. The 1983 study indicates increases in the scores on biology and physical science but show drops in earth and space travel scores. The results for the fifth grade students showed a 6.5 percent increase in overall score when compared to 1970 data. The results also indicated a significant effect favoring male students, a significant strata effect favoring private schools, and no significant interaction among these variables. The ninth grade showed a 5.2 percent increase over 1970 and also displayed a continued gender effect favoring males. At this level the strata effect was insignificant. Some results of the testing program were quite consistent with data from other studies; sex differences in science achievement increase with schooling, biology questions are easier than physical science questions, the difference in achievement between fifth and ninth graders remained constant when comparing the 1970 and 1983 tests. The SISS scores indicate a significant gain in the effectiveness of science education in promoting science achievement in fifth and ninth grade students.

Using data collected from the National Assessment of Educational Progress (NAEP), Scholastic Aptitude Test, American College Test, and the Science Survey testing programs, Blosser (31) concluded that several variables must be considered to determine how well are students doing in science and how U.S. students compare to those of other countries. When addressing the first question, the highest

correlation (20-50 percent of the variance) seems to be tied to socioeconomic background. The schools' holding power from 1940 to 1970 increased 21 percent, which in turn doubled those taking the above tests. Most of these students take no science after the 10th grade. Other variables linked to lowering science achievement are: reading comprehension, curricula completed by the student, lack of emphasis on mastery, student motivation, family motivation, and general cultural differences. When using the Science Survey test in 19 countries, it was found that our high achievers compared favorably to other countries; but when a total comparison was made, the U.S. students ranked last. The results are due to variables such as retention of students in high school and the amount of science and math taken.

Rakow, Welch, and Hueftle (226) reported the findings of the National Assessment of Educational Progress (NAEP) testing (1981-82) of 18,000 students aged 9, 13, and 17 years. Areas covered in this test included science content, science inquiry, and the role of science and technology in society. The current test scores were compared to previous tests dating back to 1969. This comparison was made in an attempt to measure the effectiveness of science education. As in previous years, the scores reflect a continued decrease by the 13 and 17 year olds. The overall lowering of scores was especially discouraging in light of the increased emphasis on science in the public schools since the last test in 1977. The only bright spot was the 9 year old group with their increase in overall score as compared to 1977. This does allow some hope, but the scores do indicate that science educators must renew their effort to provide a quality science education.

After comparing the results of the 1977 NAEP testing program and the tests given in 1982, Rakow (224) reported decreases in the ability to generalize and in the use of scientific method. The data also indicated an increase of about one percent in overall achievement among the 9 year olds. This increase was due mainly to improvement in the area of science and technology and their effects on society. Most texts in use today do not deal with this area of study effectively, and, therefore, Rakow concluded that the increases were due to influences outside the existing school curricula. The author also noted that while whites did better on both tests, the scores of blacks in 1982 were significantly better. Whether the 1982 test shows definite overall gains or losses in achievement is not clear, but the tests do indicate that only about one-half of the students tested report favorable attitudes about science.

Exemplary Programs

Meinhard-Pellens (186) conducted a case study of a national elementary science education exemplary program. The NSTA's 1982 research initiative involved conducting a Search for Excellence in

Science Education to identify 12 national elementary science exemplars based on Project Synthesis' "Desired State" criteria. The case study examined one such exemplar and involved classroom observations, interviews with the teachers and other staff, document analysis of the science coordinator's files, and administration of a survey. The data revealed that the program was well organized with strong central supply and equipment support, a supportive coordinator, excellent communications, and strong administrator support. None of the blocks to effective science instruction often reported in national surveys were found. However, observation of classrooms revealed content-oriented approaches by teachers in which didactic instruction was common. Teachers did not understand inquiry methods nor the psychological complexity of the science concepts.

Bonnstetter (32) administered questionnaires to compare characteristics of teachers of exemplary programs with those of teachers in general. Teachers in exemplary programs seem to be older, have more teaching experience, are more likely to have graduate degrees, and have had recent experience in college credit courses. Their curricula tend to be locally developed and emphasize the use of hands-on laboratory experiences rather than lecture. Characteristics may indicate the rudimentary elements needed to develop a model of excellence in science teaching.

Lederman (160,161) attempted to delineate classroom variables related to students' conceptions of the nature of science. Twenty-five classroom variables were found to be significant for both overall tentative conceptions while twelve were found to be scale-specific. In general, "successful" classrooms were typified by frequent inquiry-oriented questioning with little emphasis on rote memory. Implicit references to the nature of science were commonly found. Furthermore, successful teachers were pleasant, supportive, and frequently used anecdotes to promote instruction and establish rapport. Classrooms exhibiting large changes in overall conceptions, but not with respect to notions of the tentative nature of science, were characterized by emphasis on the depth, breadth, and accuracy of content.

Regional Studies

Yager and Bonnstetter (321) found no significant change in perception of science by persons in any of the four age groups (9, 13, 17, and 24-35 year olds) when comparing the 1977 National Assessment of Educational Progress Study (n=2500) and the follow-up 1982 study conducted in Iowa (n=700). When comparing age groups in both studies, significant trends were noted dealing with attitudes concerning teachers, subject matter, success, and future use of studied materials. The older the age group, the less likely they were to be positive toward their experiences in the science areas. The authors felt that with the current outcry for improved science curricula these

negative attitudes would have to be overcome to insure continued support.

Sousa (264) compared the results of two surveys sent to New Jersey science supervisors in 1978 and 1982 regarding the status of secondary science education in their schools. Trends that developed during the four-year period were compared to national trends revealed in recent studies. The comparison showed that New Jersey faces many of the same problems in science education found across the country. Instruction time in science, double laboratory periods, and the use of national curriculum studies have all declined. Respondents also reported a marked increase in the number of science teachers leaving the classroom for jobs in business and industry. The recruiting of qualified teachers was a diffucult task. Over nine percent of the public schools reported having to use teachers with emergency certification in science to meet their staffing requirements. Difficulties in using staff effectively, in obtaining adequate financial support, and in providing professional development programs were the major concerns of science supervisors.

Rhoton (234) conducted a study to investigate the nature of science education in Tennessee as perceived by science teachers and principals. A stratified random sample of 320 science teachers and 220 principals was surveyed. The major findings included: (1) Major discrepancies existed between what teachers and principals perceived as the nature of science education and what they considered desirable practices. (2) Grade level assignment and degree level were factors which contributed to differences in perceptions of science teachers. Years of experience in education and degree level were factors which contributed to differences in the perceptions of principals. (3) Programs were characterized in the following ways: (a) The major purpose of science education is to provide knowledge: facts, concepts, and principles of science. (b) No consistent pattern existed in planning programs. (c) Lecture/discussion is the predominate instructional technique. (d) The major resources for science teachers are other teachers, principals, regular college courses, and local district in-service programs. (e) The primary constraints are lack of sufficient funds for purchasing equipment and supplies, inadequate facilities, and lack of articulation of instruction across grade level. (4) There was little compatibility between the characteristics of science education in Tennessee and those components identified in the literature.

The purpose of a research study conducted by Lane (151) was to investigate science teachers' perceptions of the relevancy and implementation of the Nashville-Davidson County (Tennessee) science curriculum policy for grades seven, eight, and nine. The instrument used was a questionnaire. The sample consisted of 83 science teachers. Over 60 percent of the sample had students participating in science fairs within the past two years, and 50 percent required student research papers. Over 70 percent of the respondents did not recommend elimination of concepts from the curriculum. Concepts

chosen for integration into the curriculum included current events in science, sex education, space science, astronomy, technological effects on society, and chemistry in the home. The findings indicated that teachers taught most frequently those concepts perceived as most relevant. Questioning, organizing information, and problem solving were knowledge skills or processes most frequently incorporated into teaching formats at all grade levels with experimenting and analytical thinking incorporated the least. Teachers devoted most time weekly to interpreting data, formulating generalizations, and problem solving. Least time was devoted to laboratory investigations and demonstrations, which may be correlated with the lack of supplies that was perceived as the greatest barrier to teaching science. Other barriers included oversized classes, student apathy/lack of motivation/lack of interest, and poor calibre of student. Although the curriculum policy was relevant and utilized, support for its implementation appeared lacking. It was recommended that: (a) teachers have access to equipped laboratories; (b) science classes have maximum enrollments of twenty-five; (c) teachers seek unique laboratory situations in the community; and (d) more opportunities be provided for students' interaction with people in science--adding new dimensions to their perceptions of science and scientists.

Teacher Shortages

Several states have developed programs that are aimed at solving the shortages of qualified science and mathematics teachers. McGeever (181) found that successful federal, state, and local programs share several factors: the programs were based on identified needs, the programs continued as long as the need existed, there was close cooperation among participating agencies, each kept trainees together throughout the program, each involved practice teaching that included teaching units from easy to difficult subject matter, and all programs subsidized tuition costs.

Olstad and Beal (207) sent questionnaires to all science and mathematics graduates of the University of Washington who completed the secondary teacher certification program during the years 1976 and 1980. Using this questionnaire, the authors determined that the assumption that a reservoir of talent is available to teach science and math was false. There does not appear to be any single factor that would encourage a previously trained teacher to again seek a teaching position. A combination of factors seem to be turning teachers away from the profession. The most important of these seem to be job satisfaction, salary, available positions in the right location, and job security. None of these factors will be easily solved and almost all solutions in some way fall short in an attempt to bring back teachers who have left the profession.

Lashier and Ryoo (153) identified age-specific variables of science teacher survival rates, incoming number of new teachers, and

the rate at which science teachers change age cohorts in Kansas. These three variables were used in a five year longitudinal study of all the physics and chemistry teachers in Kansas to project the need for teachers in 1985 and in 1990. The study indicated that the teachers 40 years and older comprised 33.5 percent of the physics/chemistry teacher population in 1979-1980 and the percentage will steadily increase to 60.8 percent by 1990. The high turnover rate of science teachers 29 years old and younger is also contributing to the shortage of qualified physics and chemistry teachers. The cohort component population projection method outlined in this study was recommended for use in other states to document the age specific characteristics of the science teacher population.

Blosser (30) cited research form New York, Iowa, and Washington that indicated a drop in science graduates of 49 percent, 16 percent, and 30 percent respectively. Several factors affected this decline, some of which affected supply of teachers, while others affected the demand. The author noted that small districts usually had more vacancies each year and that many more teachers with little or no experience were hired by these districts. Larger districts, on the other hand, had more teachers with master's degrees and more teaching experience. Currently the supply of science majors is insufficient to meet the demand for full-time science teachers; and, therefore, districts will be forced to use minimally qualified teachers.

Reismer (231) estimates that a minumum of 3600 additional mathematics teachers and 1800 additional science teachers will be needed at the secondary level over the next several years. Even though the secondary student population will be decreasing over this period, higher graduation requirements will cause the demand for qualified teachers in science and mathematics to rise.

Hirsch (122) reported that during the first three years of the decade, Michigan saw a decrease of 7.4 percent in certified biology teachers, a 4.9 percent decrease in chemistry teachers, and a 10.9 percent decrease in physics teachers. He also found that 91.2 percent of the current biology teachers had at least a minor in biology, 78.1 percent of the chemistry and 64 percent of the physics teachers also had at least minors in these areas. The typical teacher of secondary science had 16.5 years of teaching experience and held a master's degree. The author made suggestions dealing with teacher certification and also suggested summer training sessions to upgrade those teachers already teaching, especially those with less than a minor in the area of science being taught.

The American Chemical Society's Chemistry Education Task Force (13) reported that the public's misunderstanding of chemistry is widespread. The report continues by saying too little science is taught at the elementary level due mostly to poorly prepared teachers in the field of science. To compound this problem, the task force also found no programs to assist teachers in improving their skills nor were there adequate teaching materials available. At the

secondary level, few who teach chemistry have real subject matter competence and those who do are being moved away from teaching in increasing numbers. There also seems to be very little organized help to maintain or improve skills at this level. Colleges and universities also are experiencing similar problems. Chemistry seems to be a neglected liberal art. Against this background the task force formulated 40 recommendations dealing with national concerns, all educational levels, chemistry careers, and the interface of industry and education. These recommendations are aimed at varied audiences and range in scope from global to minute.

Technology/Microcomputers

The Technical Education Research Center (282) reports that even though the development of computer software is expensive and risky, the production of such software is high. A large amount of software is available, but more high quality classroom usable software is needed. Of major concern during this development should be software that teaches problem-solving skills, empowers students, and addresses process objectives.

Summary

Studies related to achievement indicate pupils have made some gains at the elementary school level. Data regarding middle school studies present conflicting data of small gains or small declines. Older students continue to have less posititve attitudes than younger students.

Characteristics of several exemplary programs were reported. The variables identified generally agree with those reported in previous studies.

Data reported regarding teacher quality and supply are in agreement with most previous research. There appears to be an increasing trend for individuals who leave the teaching profession to remain in another occupation; the pool of potential teachers does not appear to include many of these people.

Scientific Reasoning

Introduction

A considerable number of studies were reported during 1984 that were concerned with the development of aspects of scientific

reasoning. Most of these have their roots in developmental theory, most notably the work of Piaget. The studies were organized into the following categories: Correlates of Scientific Reasoning, Training Studies, Effects of Science Instruction, Effects of Grouping, Testing Methods, and Problem-Solving.

Correlates of Scientific Reasoning

Science Processes and Attitudes

Rakow (225) used 17-year-old students (N=1955) to investigate the influence of student and classroom characteristics on inquiry ability. Results indicated that the Model of Educational Productivity accounted for 24 to 32 percent of the variance in skills for the general population. More specifically, ability alone accounted for between 17 and 22 percent of the variance for the general population. Little difference in the prediction of inquiry skill levels for males and females using the model was found. In addition, for the non-white students, the model accounted for only 18 percent of the variance, while ability accounted for an additional 6 percent of the variance. This would suggest that little is known about the factors contributing to inquiry science skills of non-white students.

Yeany (323) used 741 high school science students to search for a learning hierarchy among the skills comprising formal operations and the integrated science processes. The two tests used were: Group Assessment of Logical Thinking (GALT), which measured performance on six Piagetian cognitive modes; Test of Integrated Process Skills (TIPS II), which measured performance on five integrated process skills. Results demonstrated the existence of linear and branching relationships among the skills examined, most of which fit the hierarchies used in the development of current curricula and classroom practices. The results also indicated that students may not be able to acquire certain scientific process skills until prerequisite cognitive skills are developed.

Lee (162) investigated the relationships among attitudes concerning science, formal reasoning ability, type of senior high school, grade, and sex in Taiwan. The sample was drawn from three types of senior high schools--commercial, industrial, and general, by use of the stratified sampling method. The total sample was 540 students ranging from tenth to twelfth grades. The Scientific Attitude Inventory and Logical Reasoning Test were administered to all students to assess their attitudes concerning science and formal reasoning ability.

Moral Development

Using 99 tenth grade students, Zeidler (326) obtained measurements of formal reasoning and principled moral reasoning ability. The findings support the notion of hierarchical relationship among such variables as proportional reasoning, controlling variables, and probabilistic, correlational, and combinatorial reasoning. Factor analysis also provided evidence that the variables represent specific cognitive structures that are interdependent and precede operations in development. There also seems to be a significant relationship between formal reasoning and principled moral reasoning. Combinatorial and correlational reasoning were found to account significantly for the variance (22 percent) in principled moral reasoning.

Zeidler and Schafer (326) conducted research to examine how science content knowledge, moral reasoning ability, attitudes, and past experiences mediate the formation of moral judgments on environmental dilemmas. The study was conducted in two phases using environmental science majors and nonscience majors of college age. Phase One determined if environmental science majors exhibited higher levels of moral reasoning on nontechnical environmental social issues than on general social issues and examined the extent to which possible mediating factors accounted for differences in moral reasoning. Phase Two was qualitative in nature, the purpose of which was to observe and identify trends in conversations between subjects as to how certain mediating factors are revealed as people form moral judgments. The framework on which this study was constructed incorporates a progressive educational position; a position that views science education as being interdisciplinary, and a social means to a social end.

Cultural Differences

To test the hypothesis that cultural diversity contributes to the development of formal reasoning Lawson and Bealer (157) sampled adolescents from three predominately white middle-class communities located in areas that varied in the extent to which they offered cultural diversity (i.e., rural, suburban homogeneous, suburban heterogeneous) and administered a test of formal reasoning and a test of analytical intelligence. Results showed significant differences in formal reasoning in favor of the suburban heterogeneous sample on complex reasoning items. The suburban groups showed equal performance (but superior to the rural Ss) on the test of analytical intelligence. On the less complex reasoning items and on one item embedded in a rural farming context, the rural Ss showed relatively better performance. The authors concluded that support for the hypothesis had been obtained and that this implies that teachers who attempt to provoke formal reasoning in their students by asking them to consider the pros and cons of alternative points of view are likely to receive little support from communities in which this instructional approach is most needed.

Gerace and Mestra (99) reported on studies aimed at the interplay of language in various problem-solving tasks and its effects on Hispanic undergraduates in science and engineering programs. Findings indicate that Hispanic students are under-prepared in comparison to Anglo students. The areas of difficulty seem to be associated with linguistic processing and semantic difficulties and not necessarily the result of difficulties in the content areas.

Cohen (53) administered 10 Piagetian-type tasks to Native Americans in an attempt to deternine if there are unique ways of Navajo thinking that could account for a consistent lag in achievement levels, especially after seventh grade. The investigation examined whether selected spatial abilities were delayed or advanced in Navajo students as compared to an equivalent non-American Indian student sample: grade six (n=22), grade eight (n=20), and grade ten (n=24). The results indicated that further investigation is needed because the spatial ability of both groups seemed to develop at approximately the same rate and, therefore, would not be the primary cause of the lag in achievement levels.

Other Cognitive Attributes

DeHernandez, Marek, and Renner (67) conducted a study to investigate the relationships among gender, age, and intellectual development. Random samples of 70 females and 70 males were selected, with each sex group equally divided into a low-age and a high-age group. The low-age group ranged in age from 16.25 years to 16.75 years and the high-age group from 16.76 years ot 17.25 years. The Piaget tasks selected were: Conservation of Volume, Separation of Variables, Equilibrium in the Balance, and Combination of Colorless Chemical Liquids. Data showed: (1) males demonstrate a higher level of intellectual development than females, (2) males mature intellectually earlier than females, (3) the value of the conservation of volume task as a component of battery of formal tasks depends upon whether the decisions are to be made on the basis of the total-task results or on individual task performance, and (4) there appear to be factors other than age and gender that are related to the development of formal operational reasoning.

A model for the development of scientific reasoning in adolescents was formulated largely upon the basis of Piagetian theory and tested by Stuessy (278). Included as potential determinants of scientific reasoning were experience, age, locus of control, field dependence-independence, rigidity, flexibility, IQ, and gender. Causal relationships between these variables were hypothesized a priori with strong theoretical, heuristic, and empirical support. Data collected from middle school (n=106) and high school (n=96) students from an upper middle-class suburb of Columbus, Ohio, were used to test the hypothesized model by path analysis. Significant

path coefficients resulted for these variables and scientific reasoning: age and IQ (with path coefficients of 0.54 and 0.49, repectively) were stronger determinants of scientific reasoning than were field dependence-independence (0.15) and experience (0.11). Indirect effects of locus of control (0.28) on scientific reasoning through field dependence also were obtained. Paths involving gender and rigidity/flexibility were not significant. The revised model included significant paths, which explained 61 percent of the variance in scientific reasoning.

Training Studies

Transitivity

Ehindero (78) compared performances of four to seven year old students on conservation of distance, conservation of displacement volume, conservation of area, and syllogistic reasoning in an attempt to determine if young children can be trained to use skills that are deemed necessary for making transitive inferences. Thirty students were randomly selected in each age range and were then assigned into two groups of 15 subjects each--an experimental and a control group. Pre-tests were administered and a training program using the component skills approach was used with the experimental group. The posttest was administered to both groups and consisted of tasks designed to test for both specific and general transfer. The results indicated that the four to five year old experimental group performed significantly better than their counterparts in the control group ($t=2.46$, $p<0.05$). When considering the mean scores, the five - six and six - seven year old experimental groups performed significantly better on all four tasks when compared to the controls ($p<0.05$ and $p<0.01$; respectively). Results of this study seem to suggest that experience does bring along with it increased consciousness of ordered series. The author concluded that a training program is effective for making correct transitive inferences. The effectiveness of such a program will depend on the ability to identify component skills and strategies and incorporate them at a level understood by the students. This type of approach could be very useful in the teaching of abstract or rather difficult science concepts.

Controlling Variables

Long-term retention effects of two methods of instruction used one year earlier to teach field-dependent (FD) and field-independent (FI) sixth-grade students to control variables and to transfer this ability to novel tasks were investigated by Strawitz (276). The study also examined whether or not uninstructed seventh-grade students had acquired this ability on their own. Results indicated that

Treatment I (with feedback) produced better retention over time for both FD and FI students than did Treatment II (without feedback). Treatment II was more effective for FI students than for FD students. Significant main effects for treatment and cognitive style were found on each controlling variables task when the abilities of instructed and uninstructed seventh-grade students were compared. Field-dependent students who had received Treatment I significantly outperformed FD students who had received Treatment II and FD students who had received no instruction on how to control variables. Field-dependent students who had received Treatment II performed about as well as their counterparts who had received no instruction. Field-independent students who had received Treatment I significantly outperformed FI students who had received Treatment II on two of three measures and FI students who had received no instruction on all measures. Field-independent students who had received Treatment II significantly outperformed FI students who had received no instruction on two of three measures.

Rowell and Dawson (241) used a pretest--posttest delayed posttest controlled design to measure the efficiency of a program designed to increase students' effectiveness when dealing with controlling variables. The experimental materials were used on two grade eight classes, and two other grade eight classes served as controls. Assignment to these classes was random. Six test items were given to each student. Items examined crucial aspects of planned and natural experiments. The test was also given to grade nine and ten classes to provide a measure of the effects of continued practice on controlling variables. Results of the testing program revealed success of the teaching program and demonstrated that it is possible for students to construct and operate a general procedure for the control of variables.

Sneider, Kurlick, Pulos and Friedman (261) tested the effectiveness of a highly motivational program on rockets designed to teach children how to conduct and interpret a "controlled experiment." The study included both school and non-school settings. The program was completely voluntary and included 275 children 9-15 years old. Four criterion tasks dealing with the ability to control variables were used; two by individual interviews, and two were administered to groups. Cognitive tests were given and included: field dependence-independence (Find A Shape Puzzle and Water Level Task), verbal IQ (Verbal Meaning Test), and M-Power (Figural Intersection Test). The students were divided randomly into groups receiving instruction and groups receiving no instruction. The results indicated that all age groups having instruction seemed to do better. The results also indicated that the tested cognitive skills were all significant predictors of success. However, only the M-Power showed significant gains for those individuals in groups having instruction. The authors stated that the concept of controlling variables can be taught, but that the number of variables should be kept to a minimum or they should be highly salient.

Strawitz (277) examined the effects of an instructional procedure designed to teach both field-dependent and field-independent sixth graders to control variables and to transfer this ability to novel tasks. Students were randomly assigned to either a treatment group taught with a special instructional procedure adapted from Case or a group where students freely explored science equipment without receiving feedback. Three posttest tasks administered approximately four weeks after the last training session served as retention and transfer measures. Results indicted that students receiving the special instructional treatment correctly tested significantly more variables on the posttest tasks than did students in the other group. Within-group analyses revealed that the special treatment was effective for field-dependent as well as for field-independent students, while the other treatment was effective only for field-independent students.

Thomas and Grows (287) stated that if any beginning college student is found to be concrete operational, then that student needs immediate help in stimulating cognitive growth. Whatever the method is, it must take only a short period of time and be largely content-free. The authors used 39 college students as subjects to investigate the effects of the game "Master Mind" on cognitive growth. The authors hypothesized that those playing with verbal interaction (SI), and those playing with no interaction, would show greater cognitive growth than those not playing "Master Mind." The cognitive test battery was taken from the Cognitive Analysis Project. The greatest cognitive gains appeared in the SI groups where 21 percent of the subjects changed from concrete to formal reasoning. The experimental groups with no interaction showed only about half the gains in mean scores when compared to the SI. The hypothesis that "Master Mind" would provide cognitive growth was supported, but the Newman-Keuls multiple comparison test forced the rejection of the second part of the hypothesis. Problem related interaction while playing the game is essential. The authors stated that "Master Mind" parallels in many ways the nature of science, and game moves can be seen as mini experiments. It, therefore, seems appropriate to say that the game "Master Mind" can be used as an instructional game for teaching scientific processes.

Wollman (315) gave education majors in a physical science course a set of tasks analogous to a given, solved prototype-task involving pendulum knowledge to see how transfer items were handled. Some students were given a conceptual model along with the solved prototype. Others were given a general procedure for applying the conceptual model to the transfer items. The procedure helped considerably for the transfer items least like the prototype item. The model alone was also effective for certain items. In the absence of both model and procedure, students' problem solving was usually incoherent or self-contradictory. Presenting additional solved items helped marginally on an exceptionally novel item. Students' main source of difficulty, given the model and procedure, was that they were distracted by prior, concrete experience and thus failed to

follow the procedure. For most students, this difficulty could readily be overcome. A small proportion (10-15 percent) of students had more profound difficulties.

Hypothesis Testing

Gorman (102) tested the hypothesis that the true value of instructing students to falsify would only become apparent if they had to decide whether their hypotheses were right or wrong without being able to ask the experimenter. The experiment involved psychology students (n=120) and their ability to propose three-number strings that conform to a rule based on an observed string (2,4,6). The students were assigned to one of three strategies: (1) confirmatory - proposing strings that would be correct if the hypothesis was correct; (2) disconfirmatory - proposing strings that would be incorrect if the hypothesis were correct; and (3) control - testing hypothesis without any suggestions as to how to go about testing. Results indicated that once experimental feedback was eliminated, disconfirmatory instructions greatly improved the subjects' performance on the string task. The study suggests that the instructions helped the students avoid the "confirmation bias" noted in earlier research.

Proportional Reasoning

Lawson, Lawson, and Lawson (158) advanced the hypothesis that a necessary, though not sufficient, condition for the acquisition of proportional reasoning during adolescence is the prior internalization of key linguistic elements of argumentation, essentially those used in hypothetico-deductive reasoning. The hypothesized internalization, which does not occur in all individuals, presumably results in some who have acquired the ability to reflect upon the correctness of self-generated answers in a hypothetico-deductive manner, and others who have not. As an initial test of the hypothesis, 46 subjects (Ss) (mean age = 21.03 years) were classified into additive, transitional, or proportional reasoning categories based upon responses to a proportions task. Group differences were found in which proportional Ss performed better than transitional Ss who in turn performed better than additive Ss on a number of items testing Ss' abilities to identify, generate, and use the linguistic elements of argumentation. Further it was found that some Ss who were successful on the linguistic items failed the proportions task, but no Ss who were successful on the proportions task failed the linguistic items. This result supported the hypothesis that the internalization of the linguistic elements of argumentation is a prerequisite for proportional reasoning and, by inference, other advanced reasoning schemata as well. Science courses attempting to help students reason more effectively should attempt to engage students in logical argumentation whenever possible.

Harvey (114) sought to determine whether a teaching machine could be used to improve the formal reasoning ability of freshman college chemistry students at a small New England community college, particularly in regard to the concept of ratio and proportion. Fifteen students from an existing class were randomly assigned to the experimental group, while the remaining seventeen were assigned to the control group. Treatment consisted of exposure to from 16 to 48 frames of ratio and proportion principles and applications, and sixteen multiple-choice questions controlling machine advancement and feedback. A t-test was applied to pretest and posttest means, and in all cases no significant difference was found.

Analogical Reasoning

Zeitoun (328) presented a theoretical framework for a detailed description of a model for teaching scientific analogies. The model contains a basic theoretical framework and proceeds through nine stages of development with the students. The author feels that the General Model of Analogy Teaching is flexible and provides different alternatives. The model also exposes many areas of research that are relevant to teaching analogies that need investigation.

Effects of Science Instruction

Wilson and Wilson (310,311) administered a group test of formal reasoning to all students beginning either the two-year National High School or the one-year Preliminary Year program in Papua, New Guinea, in 1980 at the beginning of their programs. At the end of the programs they took the same test again. Piagetian cognitive levels obtained were compared with grades in science courses. Results showed: (1) considerable numbers of students at a "transitional" level on each occasion, (2) low correlations between cognitive level and science grades, and (3) significant development in levels of cognitive thought during the National High School program. Only 8 percent operated formally on the initial test; two years later, 18 percent were operating formally and 37 percent were at a transition stage. It is suggested that a knowledge of the cognitive level of students could be a particular value to teachers at this stage.

Little (169) conducted a study to determine the instructional effectiveness of a programming technique known as structured programming on the programming achievement in the BASIC language and logical thinking skills of secondary school students. The influence of three other variables--gender, cognitive developmental level, and engagement--on the two dependent measures was also investigated. Two hundred fifty-five students in grades ten through twelve participated. The treatment group (n=158) underwent 12 weeks of structured programming instruction. Engagement of treatment students during regular class and at the computer was assessed during this time. Both

treatment and control students (n=97) took posttests of programmming achievement and logical thinking. The following conclusions were drawn: (1) Structured programming appears to be an effective instructional vehicle for teaching programming skills. (2) Males scored significantly higher than females on programming achievement in the control group. In the treatment group, differences were reduced to zero. (3) Formal operational students scored higher than concrete/transitional students on both the programming and logical thinking achievement measures. (4) Females scored higher on the logical thinking measures than did males.

Lawson and Bealer (156) administered five items requiring use of proportional, probabilistic, and correlational reasoning to students in grades 6, 8, 10, and 12. Proportions are taught in the school district in grades 7 and 8, probability in grade 10, and correlations are not taught. Based on the hypothesis that successful performance is due to classroom instruction, improvements on the proportions item were predicted between grades 6 and 10 and improvements on the probability items were predicted between grades 10 and 12. Actual gradewise improvements did not correspond well with predictions. Yet performance did correlate significantly with enrollment in classes such as chemistry, physics, and trigonometry. It was argued that successful qualitative reasoning arises as a consequence of the process of equilibration, and influences one's selection of course work.

The purpose of a study by Watson (301) was (1) to examine whether there were changes over a period of four years in the Piagetian cognitive levels of college students who majored in the sciences and in the humanities, (2) to examine the relationship between the cognitive levels of these students and various scholastic variables which might account for changes in cognititon, and (3) to determine which variables could be used in the construction of prediction equations. The study was limited to a sample of thirty-eight senior male students at Rutgers. These students participated in studies on Piagetian theory when they were freshmen. The science group consisted of seventeen students originally selected from introductory level courses in physics and mathematics who had selected majors in these areas. The humanities group was comprised of twenty-one senior students originally selected from introductory level English courses and who had designated majors in non-science areas. Pretest and posttest data were gathered through the use of clinical method using the Chemical Combinations Task and the Inclined Plane Task. The following results were found: (1) Scores of the two groups did not differ significantly at the freshman level. (2) Scores of the science group were significantly higher than scores of the humanities group during their senior year. (3) Scores of the science group increased significantly from pretest to posttest. (4) Scores of the humanities group increased significantly from pretest to posttest only on the Inclined Plane Task. Significant relationships were noted for pre- and posttasks, SAT-Math, SAT-Verbal, SAT-Total, science/math G.P.A. and humanities credit hours.

Reif (230) investigated the relationship between remedial instruction in the natural sciences and mathematics and changes in the reasoning patterns of freshman university students enrolled in remedial courses to determine: (1) the effect of instruction in basic science content area skills on the development of porportional reasoning and the ability to control variables; (2) the effect of prior experience in science and mathematics on the development of formal reasoning abilities; and (3) subject area biases in instruments used to assess the development of formal reasoning patterns. Science and mathematics classes comprised the experimental groups; non-science basic skills classes were used as a control. A paper-and-pencil test was constructed. Twelve items required variables to be separated and controlled, and six required the application of proportional reasoning. A background information questionnaire was used to determine the age and sex of each subject and the number of previously completed high school- and college-level mathematics and science courses. Pretest and posttest comparisons showed significant improvement for most groups with respect to both the ability to control variables and to apply proportional reasoning. While patterns of performance differences suggested subject area dependencies, statistical analysis indicated that initial conditions and performance were significant factors related to improved perfomance. The effects of instruction in basic skills appeared to be independent of prior instruction in science and mathematics. In addition, tests used to assess reasoning abilities appear to be unbiased by subject content.

A biology course for students in the Educational Opportunity Program at the University of Washington was evaluated by Fields (85) to determine the effectiveness of the instructional objectives and teaching strategies in developing reasoning skills. Data were collected for the 151 students enrolled in the course during five quarters (Autumn 1976 to Spring 1978). Students in two standard introductory biology courses (one for non-majors, the other for pre-majors) were used as reference groups. The ethnic composition of the test group was Asian (41), Black (62), Hispanic (22), Native American (12), and Economically Disadvantaged White (14), whereas the reference group students were mainly white. Test and reference groups were given locally developed paper-and-pencil pre and post Logical Reasoning Skill Tests to assess the entry and exit levels of reasoning skills. Included were: class inclusion logic, control of variables, proportional reasoning, syllogistic reasoning, and combinatorial reasoning. Analyses of the pretest indicated that the scores of the test group students were significantly lower than those of the reference group students in all categories tested. Some of the reasons of the lower performance were identified. Many of the test students (1) were unable to discriminate between critical and less important information, (2) had poor reading skills, (3) lacked confidence in their own reasoning ability, (4) were impulsive rather than reflective in solving problems, and (5) failed to make inferences. In the posttest, the test group students demonstrated significantly improved reasoning skills, whereas the reference groups

showed no gain. Nevertheless, posttest scores of the test group remained significantly lower than those of the reference groups. Bloom's (1956) Taxonomy of Educational Objectives was used to classify the course objectives. They were then evaluated on the basis of the identified educational needs of the test group students. An assessment of the instructional strategies indicated that the strategies, rather than the objectives, were responsible for improving the reasoning skills of the test group. However, it was concluded that the effectiveness of the course could be increased by including a greater number of higher level educational objectives.

Effects of Student Grouping

Lawrenz and Munch (155) conducted a study to discover if grouping students in the laboratory on the basis of their formal reasoning ability affected (1) their science content achievement, (2) their formal reasoning ability, (3) the learning environment in the laboratory, and (4) the relationships between individuals in a particular group. The laboratory groups for three physical science classes for preservice elementary teachers were arranged as follows: (1) one class with students of unequal reasoning ability grouped together, i.e., one highly developed formal reasoner per group (the heterogeneous group), (2) one class with students of similar reasoning ability grouped together (the homogeneous group), and (3) one class arranged in groups according to the desires of the class members (the student choice group). The three classes were compared using pre- and post-scores on content and formal reasoning instruments and scores for classroom environment and social relationships. Results indicated that the groupings as described had significantly different effects on science content achievement but not on any of the other questions posed above. The students in the class with laboratory teams grouped by student choice had significantly lower science content scores than the students in the classes with teams formed using either the heterogeneous or homogeneous grouping procedures. The difference between the heterogeneously and homogeneously grouped classes was not significant at the 0.05 level.

Testing Methods

Staver and Pascarella (272) investigated effects of various methods and formats of administering the Mr. Short-Mr. Tall problem. The task was presented using four methods: (1) individual clinical interview, (2) group presentation of task followed by paper-and-pencil problem with illustration, (3) group administration of paper-and-pencil instrument with illustration, and (4) group administration of paper-and-pencil instrument without illustration. Each method included four formats: (1) completion answer with essay justification, (2) completion answer with multiple-choice answer with

multiple-choice justification, (3) multiple choice answer with essay justification; and (4) multiple choice answer with multiple choice justification. Three hundred seventy-six college biology students participated in the study. A 4 X 4 factorial design with method and format of assessment as the main effects was used. Results showed that neither method nor format of assessment accounted for significant amount of variance in student performance. The overall interaction remained nonsignificant.

Staver (273) conducted a similar study with the mealworm problem which requires students to control variables. The subjects were 253 students enrolled in a freshman level biological science class. The design was a 3 X 4 factorial design with method and format of assessment as the main effects. The task was presented by three methods: (1) individual clinical interview, (2) group presentation of task followed by paper-and-pencil problem with illustration, and (3) group administration of paper-and-pencil instrument with illustration. Each method included the four formats as described in the preceding study by Staver and Pascarella. Regression analysis with the individual as the unit of assessment revealed that format but not method of assessment accounted for a significant amount of variance in student performance. The overall interaction was not significant. Staver concluded that these two studies clearly demonstrate that the method of administration for two separate Piagetian tasks of different reasoning patterns exerts no influence on subjects' scores. The format of assessment, however, can influence scores. The case for assessment of Piagetian reasoning patterns by group methods is, in the investigator's judgement, strengthened.

Hale (107) reported the results of field trials of a Computer Animated Science Process Skills Test. The purpose of the project was to develop a valid, reliable computer-based test of integrated process skills that employed both graphics and animation. The trials were conducted with more than 150 students in grade nine through college level. The results indicate good reliability with different and discrimination indices within expected limits. This computer testing program could represent an alternative for classroom assessment as well as for research and evaluation studies.

Morgenstern and Renner (197) attempted to ascertain which of the Educational Policies Commissions' ten rational powers are measured by commercially available, standardized tests in science. A universe of standardized tests was defined and 12 specific tests were randomly selected for analysis. All instruments were validated by a panel of experts, as was a training program for the four teacher-evaluators who applied previously-evaluated criteria to each test item to determine which rational powers had to be used in responding to the item. Seven of the 12 standardized tests analyzed in the research required that students use only the rational power of recall in responding. In fact, approximately 90 percent of the items analyzed from all tests required only recall. Students were required to use other rational powers only rarely when responding to a test item and the use of the

rational powers of comparing, imagining, and analyzing was not necessary on any of the test items examined. The conclusion was drawn that the producers of standardized tests are not concerned with measuring student achievement of the rational powers.

To obtain reliable and valid measures of cognitive development in group settings, the Test of Logical Thinking, a paper-and-pencil test of formal reasoning ability, was developed by Tobin and Capie (291). It was administered to high school students, and alternate forms were then devised.

Problem Solving

Onawola (208) investigated the effects of differences in the cultural contexts of a verbal problem upon college students' problem solving mechanisms. He also investigated differences in the non-verbal problem solving mechanisms of subjects from two different cultures. The samples were comprised of 80 male Nigerian and 26 American students who were enrolled at the University of Pittsburgh. The 26 American students were matched with 26 Nigerian students who were drawn from the larger group (n=80) which formed the core of the study. Subjects in each national group were randomly assigned to two treatment groups. Each group received a science-related verbal problem written in either a Nigerian or an American cultural context. The Tower of Hanoi problem was also administered to all the subjects. The data were analyzed by using protocol analysis information theorems, analysis of convariance, multiple regression, and several other statistical techniques. The major findings were as follows: (1) There was no significant difference between Nigerian and American cultural context problems in terms of measures of information flow. (2) The Nigerian and American subjects processed verbal problem information differently. (3) The Nigerian subjects recalled significantly more keywords in the Nigerian context problem than in the American context problem and recalled fewer keywords than the American subjects in both cultural contexts. (4) The Nigerian and American subjects differed in the protocols they used in verbal and non-verbal problem solving.

Ronning, McCurdy and Ballinger (238) found research in problem solving to be primarily concerned with problem-solving methods and with degree of knowledge acquisition. A brief argument was advanced that this conceptualization is incomplete because of failure to consider individual differences among problem solvers (other than in problem-solving methods and extent of knowledge). They argued that a theory of problem-solving instruction must take into account all three areas. Evidence for the argument was presented in the form of data on problem-solving success in junior high school students with extreme scores on Witkin's field independence-field dependence measure of cognitive style. Problem-solving protocols were examined as a second source of data. Field independent students significantly

out-performed field dependent students on the problems. Examination of protocols revealed consistent performance patterns favoring field independent students.

Good (101) defined human expert problem solving in science and attempted to account for scientific discovery. The ideas, attributed largely to Herbert Simon, were used in a description of BACON.5, an expert problem solver machine that discovers scientific laws using data-driven heuristics and "expectations" such as symmetry. Trial-and-error search of data-driven scientific discovery was drastically reduced when the BACON.5 system was altered to include expectations, such as symmetry, which have been influential in "real" (i.e., human) discoveries of scientific laws. A discussion of the implications of BACON.5-type research for traditional science education research recognized the importance of qualitative understanding of the relationships among "pieces" of a physical or biological system.

Summary

The elements of cognitive development, science process skills, inquiry, problem solving, and scientific reasoning are clearly interrelated; thus, summarizing the results reported in this section must be viewed with care due to the obvious risk of over simplifying. From the studies reviewed, and from other results, it can be seen that student, classroom, and cultural/societal characteristics all have a bearing on the development of reasoning and inquiry process skills. Age (or more probably, development), intelligence, field independence, and experience were all found to contribute to development of inquiry skills. Various aspects of the skills needed in inquiry, such as identifying and controlling variables, can be taught. There appears to be a hierarchical relationship among cognitive skills, lower inquiry skills, and integrated process skills. Well defined objectives and instructional strategies contribute to the development of inquiry and problem solving skills; presentation of models and procedures, especially for disconfirming hypotheses, were found to be effective in aiding student problem solving.

Elementary School Science

Introduction

A total of 28 studies are reviewed in this section; four deal with the lower grades in elementary school, 24 with the upper levels. Studies in the last category have been further subdivided into five areas for convenience: student achievement, student conceptions and misconceptions, student curiosity and attitudes, teaching methods, and technology/microcomputers.

Lower Elementary

Cohen (54) reported the results of a study designed to investigate what effects two different teaching strategies would have on the development of logical structures, among second graders. Four intact classes took part in this study; two (control) classes receiving instruction involving working at desks and manipulation of materials based on predetermined behaviors and not children's interests; while the other two (experimental) classes received instruction encouraging them to work on the floor and to examine whatever phenomenon they were exploring by moving about and/or moving and manipulating the apparatus, and to use them in a variety of ways dependent on their own interests. Data were collected using a battery of six Piagetian-type tasks. The Chi-square one-sample procedure was used to determine if there was any direct treatment effect and also to see if gender had any effect on the development of reasoning.
It was determined that gender had no effect, while treatment did affect the development of reasoning; experimental subjects outperformed control subjects. It was concluded that teachers must take an active role when their students are using manipulatives; they should act as guides encouraging students to examine materials from many vantage points and to utilize materials in ways which seem appropriate to the students' interests and level of understanding.

The main purpose of a study by Perry (216) was to investigate the order of acquisition of notions of qualitative speed. The specific notions were the intuition of speed and the elaboration of relations of speed involving qualitative and extensive operations. Fifty-eight subjects in grades one, three, and five were administered ten tasks modified from those experiments and research described by Piaget and other researchers. The results indicated that an array of prerequisite, equivalent, and independent relationships existed among the ten tasks. The levels of difficulty implied within the hierarchy formed confirmed, in part, the evolution of reasoning found by Piaget. The findings also indicated that the concepts investigated were interrelated and separable into distinct categories based upon spatial and temporal aspects of the motion. The alignment or nonalignment of objects either spatially or temporally provides indicators of the difficulty of the experiment presented. No gender differences in performance were found.

Isaacs (133) reported on research currently under way to develop a measurement tool to evaluate the development of process skills. The test is designed to meet seven criteria (not slanted toward any particular subject area). Three versions of Form 1 were administered to 310 Jamaican students in grade three and plans are under way to test all six versions of the test in Barbados, Belize and Jamaica. The author is hopeful that the tests could be a useful research tool or an accurate measure of learning due to curriculum development.

Severeide and Pizzini (248) suggested that play and science are complementary aspects of problem solving. While science lends structure to the activity, play allows the student's experiences and curiosity to be used on the problem. The authors reported that considerable research indicates when teachers incorporate guided play into activities, fluent problem solving skills can be developed.

Upper Elementary

Student Achievement

Doran and Jacobson (73) reported the results of the Second International Science Study. The test results indicated that science programs at the fifth grade level seem to have a positive impact on both the science achievement and attitudes toward science. The current results show a significant gain on items assessing the higher level thinking and process skills, when compared to the 1970 results. Slight losses were noted in earth and space science while biology achievement showed the greatest gain.

Harlen (110) summarized the findings of a national survey in Great Britain on the performance of 9,000 11-year-old children in science. The students' performance was assessed in six categories: (1) symbolic representation, (2) use of apparatus and measuring instruments, (3) observation, (4) interpretation and application, (5) design of investigations, and (6) performance of investigations. Overall patterns formed were: good performance for symbolic representation but showing a wide disparity between forms of such representation; generally good performance when using apparatus and measuring; high performance using familar situations for observation, good use but poor explanations for interpreting applications, generalized and partial answers for design of investigations, and a context-dependent pattern for performance of investigations.

Abeti (1) tested 200 primary level children in Uganda in an attempt to identify specific social environmental factors of the home that are related to science achievement. Three instruments were given to the children in a group setting: a mental ability test, an achievement test, and a student questionnaire. The findings indicate that: (1) boys achieved better in science than girls, (2) younger students achieved better than older students at the same grade level, (3) brighter children attended school more regularly than dull students, and the bright boys attended more regularly than bright girls, and (4) the social environment of the home was not significantly related to achievement in science. However, sub-variables of parental unity, parental status, and family conditions were found to be significantly related to achievement in science for boys. The study also confirmed the positive correlation between achievement in science and intelligence quotients (sample = 0.50).

Student Conceptions and Misconceptions

Mintzes (191) reviewed current research which indicates a wide range of unanticipated learning outcomes through the interaction of naive theories concerning human anatomy. In some cases, instruction seems unable to uproot such theories, while in others students develop dual belief systems. There even exist situations where instruction reinforces these naive notions. A sense of dissatisfaction must be created to uproot firmly entrenched student ideas. Five lesson plans (Gaining First-Hand Experience, Suggesting Alternative Explanations, Debating Competing Viewpoints, Considering Discrepant Observations, and Reorganizing Cognitive Structure), each concentrating on a different aspect of conceptual change strategy, are currently being developed. Preliminary work indicates that this approach to conceptual change is highly motivational and may result in the accomodation of scientific concepts.

Smith and Anderson (254) conducted a case study as part of a larger study of teachers' use of curriculum materials in planning and teaching fifth-grade science. The case study focused on one of the nine teachers observed teaching an activity-based unit on plant growth and photosynthesis. Although the teacher became aware that her students held certain misconceptions about plant growth, she was unsuccessful in helping them replace their misconceptions with the scientific conceptions she wanted them to learn. The analysis revealed several factors that contributed to this disappointing result. The teacher and the curriculum developers held different views about learning and the nature of science, and several problems surfaced about the content and organiztion of the teacher's guide.

A population of SCIS students was used to investigate ecological concept formation by Cothron (61). Two researcher-designed instruments were administered: (1) Ecosystem Test: examples, principles, definitions, and attributes of the higher-order concepts: producer, consumer, decomposer, environmental factors and their interactions via the food-mineral and oxygen-carbon dioxide cycles, (2) Ecology Card Sort: free-sort categorization task to elicit the conceptual system for ecological concepts. Findings were: (1) grade and ability, not sex, were related to concept attainment; (2) sequence of concept attainment was not influenced by grade, ability, sex; (3) students recognized life requirements, interactions of organisms via food, mineral, gas exchange and community groups; however, they could not articulate attributes of higher-order concepts such as producer, consumer, environment; (4) grade and ability, not sex, influenced the similarity of the conceptual system and the discipline structure; (5) discipline experts, not elementary students, possessed conceptual systems based upon higher-order concepts; and (6) formation of a conceptual system similar to discipline structure was positively related to concept attainment.

Urevbu (294) investigated the level of concept attainment of selected energy concepts for possible inclusion in the Nigerian (Bendel State) Primary Science Project (BPSP). Subjects were taught energy concepts at three levels: descriptive, comparative, and quantitative. Results showed that levels of concept comprehension were hierarchical with a significant decrease in achievement from descriptive to comparative and quantitative concepts. The results of this study suggest the need to describe levels of concept for particular grades in the elementary school curriculum and to match curriculum with thinking strategies of children.

Solomon (263) discussed students' formation of concepts about energy, classifying responses as living/non-living, human (vitalism or activity), and non-human (supply or demand). Observations were based on class discussions and free writing, followed by questioning to check on stability of concepts. Also collected and reported were student responses (examples of energy) before/after instruction.

Smith and Anderson (255) used teacher case studies and modified teacher behavior to combat the influence of misconceptions on the understanding, by fifth grade students, of many scientific topics. Student misconceptions were identified and used to develop modification of both teacher behavior and commercial science programs. The study determined that most students had misconceptions and that teachers exhibited teaching behavior that did not take student misconceptions into account. Without modifications, fewer than one quarter of the students learned the scientific concepts studied. Once the materials were modified, and teaching behavior was altered, learning definitly improved for both sets of materials used.

Student Curiosity and Attitudes

Harty and Beall (112) reported the development and testing of the "Children's Science Curiosity Scale" with samples of fifth graders. Data concerning internal consistency, test-retest reliabilities, concurrent validity, predictive validity, and construct validity were described. Sex differences were also explored but were not found. Suggestions were made concerning future attempts at instrument refinement.

Harty, Anderson, and Enveles (111) determined the correlations among the constructs of interest in science, attitudes toward science and reactive curiosity in fifth graders (n=91). The following test instruments were used: Childrens' Interest in Science Measurements; Attitude Survey for Junior High Science; and a shortened version of the Childrens' Reactive Curiosity Scale. Significant correlations were found between science interest and science attitudes, 0.58 ($p < .001$); science interest and curiosity, 0.47 ($p < .001$); and science attitudes and curiosity, 0.40 ($p < .002$). There did appear to be a gender difference as girls had correlations higher than boys. The

tests designed to measure science interest did just that, but the tests designed to measure science attitudes and curiosity seemed to test that and more. The authors did an item analysis and found that a significant number of students consistently favored high activity involvement. The study seems to support the idea that students would enjoy science more thoroughly if the class was conducted with students' activities at the center.

Burke (38) explored trends in sex-differentiated attitudes toward science among fourth, fifth, and sixth grade students. Central questions were: (a) To what extent do males and females perceive science differently? (b) To what extent do males and females exhibit differing trends in their attitudes toward science? The subject population were 600 students from self-contained classrooms in a rural district. Major findings included: (1) By sixth grade, males and females alike agreed that the teacher would select a male as the best science student in the class. (2) Students of both sexes exhibited a significant decline in attitude toward science by the sixth grade. (3) Females at all three grades generate more positive and negative intellectual self-descriptors of their work than did males. (4) The availability of same sex scientists as role models was important. (5) The teacher was the single most important significant factor for encouraging success in science.

The purpose of a study by Hayes (117) was to determine the relationship of student attitude to academic achievement in reading/language, mathematics, science, and social studies while holding gender, grade level, and class size constant. Data were collected from 13 Indianapolis area private Christian schools. The null hypothesis was rejected at the .01 significance level for the California Achievement Test, Iowa Test of Basic Skills, and the Stanford Achievement Test, and at the .05 significance level for the Metropolitan Achievement Test. Thus, Hayes concluded that there is a relationship between student attitude toward reading/language, mathematics, science, and social studies and achievement in reading/language, mathematics, science, and social studies when extraneous variables are partialed out.

Harty and Beall (113) investigated whether differences existed between gifted and nongifted fifth graders and between genders and related subgroups with respect to attitudes toward science. Both groups (n=25) were matched on the demographic characteristics of school-site, race, sex, and socio-economic background. Gifted students were found to have more positive attitudes toward science than nongifted students and boys exhibited more positive attitudes toward science than did girls.

Teaching Methods

A study by Dertinger (68) attempted to demonstrate that an elementary student's locus of control is modifiable towards internality when the student is instructed with a mastery learning process. Subjects were 66 sixth grade students and treatments consisted of a traditional classroom--learn, test, and assign a grade--sequence and a mastery learning sequence. The pretested experimental group showed a mean difference of 2.54 points toward internality: pretest mean (22.61) and posttest mean (25.15). The pretest control group showed no statistically significant difference between the pretest mean (24.75) and the posttest mean (26.58). The posttest means of the non-pretested groups revealed no statistically significant difference in means with any of the other posttest means.

Wagner (297) investigated the relationship between achievement gains of science students in the fourth and fifth grades related to two methods of instruction and differences in the questioning styles of their teachers. The two methods were an inquiry approach and a reading-recitation approach. Achievement gains were measured in the process skills of science and in content-knowledge. Population samples were drawn from classes consisting of 178 students and six teachers at an elementary school located in central Virginia. Eight hypotheses were tested at the .05 level of confidence. The major findings were: Phase One: There was a significant difference in: (1) total achievement gains between the methods; and (2) process skills gains between the methods. Phase Two: There was a significant difference in: (1) the questioning styles of teachers between the methods. Phase Three: there would be no real difference if the questioning styles of teachers did not differ in: (1) total achievement gains between the methods; and (2) process skills gains between the methods.

Saunders and Shepardson (245) examined the effect of formal and concrete instruction on the cognitive development of sixth grade students. Formal instruction emphasized oral and written language and did not allow for laboratory investigations. The concrete instruction was organized around the three-phase learning cycle (exploration, conceptual invention, and discovery) and emphasized hands-on activities. At the beginning of the study neither group displayed an advantage in science achievement or cognitive development. At the end of the nine-month study, the concrete instruction group (n=57) scored higher on science achievement, delayed science, and cognitive development than did the formal instruction group (n=58). The percentage of students advancing from concrete to transitional reasoning was greater in the concrete instructional group. This research adds more evidence to the importance of hands-on science to promote intellectual development.

An experimental study was carried out by Walker (298) to test the effectiveness of two methods of teaching sixth grade science students

the interrelationships of batteries and bulbs via either the inductive-guided discovery or deductive exposition teaching methodologies. The study examined the relationship of cognitive style to teaching effectiveness, as well as the possible aptitude treatment interaction. The evidence from the study suggested a significant main effect for cognitive style for the initial learning variables. However, there was no main effect for teaching methodology. For the retention variable, there was also a highly significant main effect for cognitive style but no main effect for methodology. A significant main effect for cognitive style for time on task behavior was also evidenced. Again, there was no main effect for methodology. It was apparent from the study that field independent students performed at higher levels of initial learning, retention, and time on task behavior, irrespective of methodology.

Yore (324) explored Morine and Morine's assumptions regarding age and cognitive development of learners successfully utilizing two types of inquiry, specifically, structured inductive and semi-deductive. Two groups of elementary school students from grades one, three, and five were individually assessed on six conservation tasks and a multiplicative classification task. The two groups were instructed on two different science topics utilizing different inquiry strategies. The results indicated that age made a significant difference on achievement for both inquiry strategies. The effect of cognitive development was more noticeable in the less structured semi-deductive strategy in which four conservation tasks and the multiplicative classification tasks were significant.

The results of 11 studies of classroom practices used with the activity-based elementary science programs (ESS, SCIS, and SAPA) were combined quantitatively by Bredderman (35). All studies included control groups and employed techniques for coding lesson events. A composite category system was developed for combining study results. It was found that teachers using activity-based programs spent about 10 percent more time on student activity and 10 percent less time on talk than did teachers using traditional methods. More direction giving, more higher level questions, and less lecturing were also reported. Teachers trained in program use spent less time giving directions, more time on activities, and less time on talk than did untrained teachers using the programs. On the average, researchers coded slightly less student talk and slightly less student-initiated talk in activity-based classrooms.

Metcalfe, Abbott, Bery, Exley, and Wisnia (188) investigated the effectiveness of teaching science using drama. Two entire classes of 70 eleven-year-olds were used. No statistically significant difference was noted on factual recall, but significant differences were noted for more meaningful learning. Those students using drama had significantly higher scores on the explanation and interpretation phases of the test. The authors stated that two important educational implications could be drawn: (1) support for alternative approaches to teaching can be used - especially when dealing with difficult

concepts or with less able students, and (2) practical work can be carried out effectively in non-laboratory settings.

Technology/Microcomputers

Iker (130) reviewed research into the effectiveness of the "3-2-1 Contact" program (PBS) as designed to target students before entering junior high school. The research group used 50 studies involving 10,000 children, to evaluate student reactions to different kinds of material and production approaches. From the research, ten characteristics for making a successful program were identified. These were then incorporated into the actual production of the series. The research provides insight into the 8-12 year old child, specifically within the context of science and television. The author stated that this research could be very useful for science educators by increasing the effectiveness of topic selection and in the rationale used for the topic's instructional treatment.

Rowe (240) reported on the effects of "3-2-1 Contact," on two widely accepted goals of elementary science: to stimulate enthusiasm for science, and to help students gain an understanding of scientific concepts. In the study, 15 programs were tested with 192 fourth and fifth graders. The students were pretested before viewing the episodes and were again tested after viewing. There was no formal discussion of the episodes either before or after viewing. The results of the testing indicated that the children learned and retained many scientific facts, and some of the knowledge gained seemed to be of the most abstract type. The children also increased their desire to inquire independently about topics discussed in episodes. Those children who expressed the lowest interest level in science prior to the showings gave the shows the highest ratings. The "3-2-1 Contact" program reaches a younger audience than do other popular science programs and, therefore, could be very useful in elementary science programs.

The cognitive psychology of child-computer interaction was the emphasis of a three-year research project reported by Avons (18). Using 5- to 11-year-olds, issues arising from the use of computer-based simulations to promote learning were examined. Specific areas investigated were comprehension of Cartesian graphs, the ability to understand the concept of area and its relationship to the estimation of rectangular area, and the perceptual-motor limitations of young children interacting with computerized displays using a light pen. One finding reported that, contrary to prevailing views, allowing children interactive control of animated displays does not lead to detectable changes in conceptual understanding.

Summary

In general, findings reported in this section tend to agree with results reported in reviews and summaries of earlier years. Support is clear for an activity-centered, hands-on approach to teaching science for gains in science achievement, process skills, problem solving and more positive attitudes toward science. The evidence also indicates that unanticipated learning outcomes may occur due to naive theories or misconceptions held by students; modification of curriculum materials and carefully designed instructional procedures can lead to replacement of misconceptions. The use of a conceptual structure similar to the structure of the discipline to guide teaching was found to be effective in promoting concept attainment. Field independence and age were found to be related to time on task and to achievement. Additional support was reported for the hierarchical nature of development of logical thinking. There were some promising findings as a result of the Second International Science Study which reported improvement over 1970 scores in both science achievement and attitudes toward science by fifth grade students. However, the research also continues to indicate that science is still perceived by students as being more masculine than feminine and that more same-sex role models are needed to encourage students, particularly females, to consider science related careers.

Junior High Science

Introduction

A total of 26 studies related to junior high school science were reviewed under the seven headings of student achievement, student conceptions and misconceptions, student attitudes, other student characteristics, teaching methods, technology/microcomputers, and career choices.

Student Achievement

Aiello-Nicosia, Sperandeo-Mineo, and Valenza (6) investigated the relationships among Junior High School science teachers' characteristics (understanding of science processes and their ability to control variables) and student achievement in science contents and processes. Teacher ability to control variables was found to be a better predictor of achievement than was understanding of science processes.

Student Conceptions and Misconceptions

Ault, Novak and Gowin (17) conducted clinical interviews with second grade and seventh grade students in an effort to describe the effectiveness of the "Interview Vee" to reduce the interview response data to a form suitable for both pragmatic and theoretical applications. The study also demonstrated how application of the "Interview Vee" yields important insight into the long-term growth of childrens' conceptualizations of molecules. This research substantiates the potential for society to educate children in important science concepts and, more importantly, indicates that students should share in the knowledge about their own learning and knowing.

Student Attitudes

Hofstein and Welch (126) assessed and compared the attitudes of a national random sample of students involved in the Science Assessment and Research Project in 1976-77 and 1981-82. The 1977 student population consisted of 12,824 junior high students, and the 1982 sample consisted of 5,950 senior high students of this same cohort. The data indicated that the secondary school students had a slightly more negative attitude toward their science classes than did their junior high counterparts. No significant difference was noted between the groups in their perceived value of science. Secondary science teachers were viewed by their students more favorably than were junior high teachers. No significant change was noted regarding socio-scientific responsibility from 1976 to 1982. Attitudes toward science remain high as long as the subject remains abstract or is perceived as a distant concept, but when the students' daily lives are affected by the concept, the attitude scores decline. As long as students perceive science as abstract and not a personal matter, science education may not receive the long-term commitment needed from the public sector. The authors feel that an awakening of personal excitement for the intellectual power of science is needed. In order to achieve this excitement Hofstein and Welch suggested that junior high programs be aimed at increasing the students' ability to cope with scientific concepts and that the adaption of secondary programs dealing with relevant materials be incorporated into existing programs.

Other Student Characteristics

A study concerned with the relationships among field dependent-independent cognitive styles, achievement in science, the personality variables--social skills and self-reliance--and the sex of the student was conducted by Randolph (227). The study was also

designed to determine which variables best predicted performance on a test of science knowledge. One hundred fifty-one eighth grade students were administered the Group Embedded Figures Test and the California Test of Personality. Science achievement was based on the scores of the students from the Comprehensive Tests of Basic Skills Science Test. Significant correlations were obtained between field independence and science achievement ($r=0.586$, $p<.001$) and between self-reliance and science achievement ($r=0.229$, $p<.005$). Personality variables and cognitive styles were not related. This finding was not consistent with research data generally reported. No significant difference was found between the performance of males and females on the science achievement test. Self-reliance and field independence, in concert, were found to be the best predictors of achievement on a test of science knowledge.

Seventh grade life science students (n=122) from a suburban midwestern junior high school participated in a study of the relationship between selected cognitive variables and problem-solving ability conducted by Work (318). The cognitive variables were field dependence-independence, developmental level and learning/problem-solving style. The instruments used to gather the data were the Group Embedded Figures Test (GEFT), the Inventory of Piaget's Developmental Tasks (PDT), a modified version of the Kolb Learning Style Inventory (LSI), and four spatial problem-solving tasks. Data gathered from school records on the background characteristics of sex, IQ, and science achievement were included in the statistical analyses. Complete data were obtained for 87 subjects. Field independence and developmental level were significantly related to intelligence and problem-solving ability. The best problem solvers were field independent and formal operational or transitional. Individual problem-solving style was not significantly related to problem-solving ability. There were no significant sex differences for any of the variables.

Gussett (104) examined the relationship of specific reading performance objectives and science achievement in 157 fifth through eighth grade students. The information collected allowed the researcher to determine which of the selected performance reading objectives positively affected science achievement. Twenty-six of the 38 reading performance measures correlated highly with science achievement. On the basis of the findings of this study, it was recommended that studies and research effort should be directed towards determining the individual contributions of specific reading objectives to science achievement and the role of inference in middle school science.

Taglieber (280) assessed the level of science achievement of eighth grade students in the Santa Catarina (Brazil) state schools and examined the relationships between science achievement scores and background variables. The measurement instruments were built using items and statements from standardized tests and scales used in the United States and translated to Portuguese. From the results of a

pilot study, a 60-item Science Achievement Test (SAT) and a 50-statement Attitude Toward Science Scale (ASC) were constructed. Both instruments were administered to a multi-stage random sample of 2,010 eighth grade students. Two questionnaires were also administered to collect background variables. Student performance on the SAT was generally similar among regions. However, students from small cities outscored their peers from the main cities. Students from daytime classes outperformed students from evening classes. Gender, when applied to the regional data, showed statistical significance with some interesting regional differences. Four independent variable clusters were formed in the regression analyses, all of which were, individually or in a priori ordering, significantly associated with the science achievement scores. The maximum explained variance was 31 percent. The most important variables in each cluster were: (a) Student's Personal Characteristics Cluster, Attitude toward Science; (b) Family Background Characteristics Cluster, Home Library; (c) School Characteristics Cluster, Library and Science Lab; and (d) City Characteristics Cluster, and Economic Activity and Population. School and city clusters had the most influence on achievement, as measured by the SAT, but more specific studies should be conducted on these variables.

Bradshaw (34) investigated the relationship of black innercity students' perceptions of ability to expected and assigned grades in science. One hundred-one eighth graders from upper, middle and lower academic levels participated. The subjects were from low SES backgrounds. Correlations between (a) self, (b) peer, and (c) science teachers' ratings of ability; and (1) expected grade and (2) assigned grade were significant at .01 and .001 levels for males, females, and students in each academic grouping. Correlations between locus of control and the criterion variables were significant, ($p \leq .01$) for males, and students in the highest and lowest academic grouping.

Teaching Methods

Status

Mitman and Osaki (193) investigated the combination of student, teacher, curricular, or task factors that characterized effective life science instruction at the seventh grade level. Data were obtained from 11 teachers and their classes using students pre- and post-surveys including classroom observation records and curriculum content analyses. Results indicated that teachers carried out instruction through means of recitation, seatwork, and laboratory exercises (in that order). In addition, the teachers rarely made explicit reference to the historical, reasoning, social, or attitudinal implications of the subject matter.

El-Rashed (79) investigated the influence of teachers' wait-time and question levels on Saudi middle school students' science achievement and attitudes toward science. Twenty eighth-grade science teachers from fourteen middle schools within the city of Riyadh, Saudi Arabia, were selected to serve as the sample. One class from each teacher was selected randomly to be involved in this study. All teachers were given instruction on wait-time and questioning techniques. Science achievement and attitudes toward science measures were used to pretest and posttest the students. All students were taught the same six-week unit at the same time. Each teacher submitted eight recorded lectures to the investigator. The tapes were transcribed and all questions classified independently by the investigator and two other science educators. The tape recordings were also used to measure each teacher's mean wait-time. The following conclusions were generated: (1) Student achievement tended to be greater when narrow questions were used. (2) Students' attitudes tended to be less influenced by the different combinations of the teacher behaviors studied than was achievement. (3) Variations in wait-time and question levels generated more significant differences in students' achievement than in students' attitndes. (4) The use of broad questions and extended wait-time was the only combination of teacher behaviors that significantly influenced both students' achievement and attitudes. (5) Appropriate wait-time and appropriate questioning techniques were not consistently used by most teachers. (6) More training in the use of wait-time and appropriate questioning techniques is necessary if effective manipulation of these two variables is desired.

Tobin (290) conducted a study involving 20 intact classes in grades six and seven from suburban schools in Perth, Australia, to investigate changes in discource attributable to the use of an extended teacher wait-time in a sequence of seven lessons related to probabilistic reasoning. A wait-time feedback group of 10 classes obtained a significantly higher summative achievement mean than did a control group which utilized a normal wait-time. The results indicated that teacher wait-time increased significantly over a seven lesson sequence from an average of 1.9 seconds to an average of 4.4 seconds. Discourse patterns in whole-class settings also changed throughout the study. Although the total number of utterances decreased, the average length of pupil utterances increased. Changes were also observed in the teacher discourse. The most notable of these related to the type of teacher talk that followed a pupil response to a question. Teachers tended to probe to obtain further pupil input rather than mimicking pupil responses. The average length of student discourse and the proportion of student reacting were significantly related to summative achievement. The results of the study indicated that the use of extended teacher wait-time in whole-class settings can improve teacher and pupil discourse characteristics.

Holliday, Whittaker, and Loose (128) investigated the differential effects of verbal aptitude and study questions on comprehension of fossil types. Eighth-grade students (n=217) were randomly assigned to a text-only, text-question or placebo treatment. The text verbally described five fossil types. The questions consisted of 28 fill-in-the-blank queries about the text. The posttest required students to visually identify and discriminate 40 fossil specimens as to fossil type. Comprehension of the concepts clearly took place - a fact substantiated by the very low scores obtained by the placebo group. As predicted, low-verbal students performed better, ($p<0.05$), when provided with a text-only rather than a text-question treatment. In contrast, high verbal students were less affected by the verbatim study questions. Main effects among these groups were also detected. Apparently such questions can overprompt students, resulting in their copying of words from a text to an answer-blank without semantically encoding (i.e., comprehending) the copied words.

ISIS Program

Clevenstine (51) conducted a study to analyze and classify the Individual Science Instructional System (ISIS) minicourse performance objectives and criterion-referenced test items according to Bloom's Taxonomy. Thirty-three ISIS minicourses and criterion-referenced tests were collected and classified. It was found that test items and performance objectives are written primarily at the Knowledge and Comprehensive levels. The materials reflect low percentages of upper cognitive level test items and performance objectives.

Management Skills

Sanford (244) frequently observed 26 junior high and middle school science classes taught by 13 teachers during the first two months of school and during two months in the middle of the year to identify classroom management and instructional organization variables related to high levels of student task engagement and low levels of off task and disruptive behavior. Sub-samples of more and less effective managers were identified, and narrative data from their classes were analyzed to describe and illustrate effective strategies for managing science classroom activities. In general, efficient routines, skill in managing group work, quickly stopping inappropriate behavior and wandering, clear communication, and appropriate pacing of instruction were found to be especially important.

Lloyd (170) investigated the effects of a priming activity on the reading comprehension of a science passage of low prior knowledge subjects. One hundred forty eighth-grade science students were administered a 32-item researcher-developed multiple-choice test to

assess prior knowledge of the topic, photosynthesis. Of these students, 99 were identified as having low prior knowledge of the topic and were thus selected as subjects for the study. The quality of their prior knowledge was also assessed by this instrument; the distractors to many of the items were misconceptions about the topic. Procedures included the pretest, a videotaped priming activity, an intervening task, a 920-word silent reading passage, and a posttest. The target priming activity and passage were about photosynthesis. A placebo priming activity and passage were about heredity. Subjects were randomly assigned into one of four treatment conditions: (1) target priming activity + target passage, (2) target priming activity + placebo passage, (3) placebo priming activity + target passage, or (4) placebo priming activity + placebo passage. The dependent variable was a 32-item mutliple choice test (identical to the pretest) about photosynthesis. Three question types were included: (1) textually explicit, (2) textually implicit, and (3) scriptally implicit items. Results indicated that a lesson which teaches prerequisite concepts does not significantly affect the reading comprehension of students with low prior knowledge. Of the three question types, the priming activity had a significant effect on scriptally implicit questions. There was no effect due to priming activity on textually explicit or textually implicit questions.

The focus of an investigation by Tobin (284) was on relationships between teaching behaviors and student engagement in 13 middle school science classes. The results indicated that seven managerial variables and four instructional variables were significantly related to student engagement rates. Also, the types of tasks allocated by teachers in science lessons were significantly related to the types of tasks undertaken by students. A canonical correlation analysis indicated significant relationships among three allocated task dimensions and three student engagement dimensions. Although teachers allocated adequate time for students to engage in investigation planning, data collecting, and data processing, the results indicated that overt engagement was prevalent only when data were collected. Attending was the predominant type of student engagement when investigations were planned and data were processed. The percentage of student time on task was approximately 63 percent. Rates of student off-task behavior tended to be consistently high across all types of allocated tasks.

Benedettie (27) investigated the effectiveness of a two-part instructional adaptation on the acquisition of science information by middle school, learning disabled (LD) students. Thirty-three seventh and eighth grade LD students from a suburban middle school participated in the study. Within each class, students were randomly assigned to either adapted or traditional instructional groups. The two components of the adapted condition were timed vocabulary exercises and a set of framed outlines that identified and sequenced major concepts for the chapter. The traditional instruction followed a discussion format suggested in the teacher's edition of the textbook. The chapter test was readministered to all students at the

end of the 14 day intervention period. Students in the combined adaptation condition demonstrated significantly greater acquisition of science information. To what extent the results were due to teacher effects was unclear. Readministration of the chapter test two weeks after the posttest indicated that the students in the adapted group maintained a significantly higher level of performance that was independent of teacher effects.

Lab Activities

McKenzie (184) assessed the effects of three instructional strategies (treatments) on the graphing achievement and engagement of 101 eighth grade students enrolled in an urban/rural middle school. One treatment group experienced a series of hands-on laboratory activities designed to teach graphing skills while another group completed written simulations that paralleled the hands-on laboratories. A third group experienced a combination of both hands-on and written simulation lessons. In addition, subjects were evaluated for their levels of cognitive development and spatial scanning ability. The following conclusions were drawn: (1) None of the instructional strategies examined appeared superior to the others in regard to level of graphing achievement attained by students. (2) Instructional strategies involving hands-on activities resulted in higher achievement than the written simulation strategy. (3) Transitional/formal operational students tended to score higher than concrete operational students on the graphing achievement measure. (4) Spatial scanning ability showed minimal relationship to graphing achievement. (5) The effects of treatment on achievement across levels of (a) cognitive development and (b) spatial scanning ability appear to have been consistent.

Padilla and Okey (210) investigated different patterns and amounts of instruction on planning experiments with sixth and eighth-grade students. A model for generating integrated process skill lessons was used to produce all lessons. Treatment One involved a two-week introductory unit on integrated process skills, followed by a one-period process skill activity per week for 14 weeks. Treatment Two involved only the same two-week introductory unit. Treatment Three was a contrast group which received only content oriented instruction. Results showed that both sixth and eighth-grade students can learn to use certain integrated process skills; growth was apparent in identifying variables and stating hypotheses. Differences generally favored Treatment One over Treatment Three. No differences favoring any treatment were found for formal operational ability outcomes.

Using 1025 junior secondary class three (ninth grade) students and twelve science teachers, Okebukola and Ogunniyi (204) investigated the effects of cooperative, competitive, and individualistic science laboratory interaction patterns on students' achievement in science

and the level of acquisition of practical skills. A 3 X 3 (interaction pattern by ability) factorial model was employed for data gathering. Significant main and interaction effects were found for both dependent measures. The cooperative group was found to be superior on the achievement measure with no difference between the competitive and individualistic groups. The competitive group, however, outperformed the others in practical skills. Additional data indicated that the mixed ability cooperative group did significantly better than the mixed ability competitive group in achievement but not in practical skills.

Moore (196) developed an instrument called the "Knowledge and Feelings about Animals Inventory" (KFAI). This instrument was used for pretesting and posttesting of experimental and control groups (measuing: student attitudes, beliefs, behavioral intentions and knowledge toward ten selected animals). One-hundred and twenty students (grades 3-8) of the University of Wyoming Laboratory School were randomly selected and randomly assigned to experimental (60 students) and control (60 students) groups. The experimental treatment group received two guided experiences with the animals totaling one hour of exposure. Students had an opportunity to touch or hold the animals and discuss animal anatomy with the investigator. Control group students did not receive exposure to the animals. Results showed that there were significant gains in attitudes, beliefs, and behavioral intentions (positive change) for both control and experimental groups. Experimental group posttest results showed significant positive gains in attitudes, beliefs, behavioral intentions, and knowledge over the control group posttest results. The most dramatic change occurred in knowledge gained, but attitudes and knowledge were found to be poorly correlated (r=0.15).

Technology/Microcomputers

Trowbridge and Durnin (292) examined learning by individuals and groups in a computer environment. Individual interactivity as a function of group size was investigated as the students manipulated pictures of batteries, bulbs, and wires on the computer screen to perform simple experiments with simple direct current circuits. This process involved high-level learning (reasoning skills and conceptual understanding). Achievement for the subjects (n=58 seventh and eighth grade students) was measured using a brief paper and pencil test and individual interviews. The study also asked the students to apply their knowledge to appropriate non-computer tasks. The findings indicated an advantage of small group usage (two to three students per group) over individual usage of computer-based instructional materials. Also, students working in groups seemed more likely to interpret questions in the way the author had intended.

McGuire and Holliday (182) investigated the effects of adjunct questions that were inserted after each of 12 computer-animated graphics sequences shown to 160 eighth-grade science students. These sequences presented two relationships in a purely spatial fashion. Four randomly assigned treatment groups received questions targeting one of the two relationships (temperature of molecular motion) over all or part of the 12 sequences. A control group received placebo postquestions. Significant interactions among treatment groups and posttest items ("low-level" comprehension) were found for each targeted relationship. Furthermore, interactions were stronger for students receiving postquestions covering all sequences. These findings extend previous research to include spatial as well as textual media.

Cameron (40) investigated the effects of two instructional treatments upon the attitudes of eighth-grade students toward animal life. This study also examined the effectiveness of the instruction upon critical thinking skills. The Cornell Critical Thinking Test assessed the students' critical thinking ability. A researcher-designed measure, the Animal Attitude Survey and Cognitive Assessment, determined the students' attitudinal and cognitive levels about animal life. The subjects of the study were 147 eighth-grade students. One experimental group (n=43), which consisted of two intact classrooms, received print material and media-based instruction on animal life issues. A second experimental group (n=43), which consisted of two intact classrooms, received print material and lecture method instruction on the same animal life issues. Both experimental groups received instruction on 15 consecutive school days during 55 minute class hours. A third group (n=61), which consisted of three intact classrooms, served as a control and received no treatment in animal life issues. Results suggested that both eighth-grade experimental groups' attitudes toward animal life improved in a positive direction. The media-based instruction group showed a superior change in positive attitude toward animal life. In the cognitive, knowledge-level area, the lecture treatment group made a slight improvement. In comparing the three groups in critical thinking ability, no significant change was detected.

Career Choices

The major objective of a study by Smith (257) was to investigate the effect of sex, mathematics achievement, science achievement, and science self-concept on the science career preferences of a sample of 411 urban black sixth- and eighth-grade students. The study was conducted in an Intermediate School located in New York City--Central Harlem. When science career preference was regressed on sex, mathematics achievement, science achievement, science self-concept, and the interactions of sex and mathematics, sex and science achievement, and sex and science self-concept, controlling for reading, only sex membership was found to contribute significantly to

variance accounted for in science career preference for sixth graders. Math achievement also contributed for the eighth graders.

Oliver and Anderson (206) evaluated the desirability of science teaching as a career as rated by eighth grade students. The instrument developed allowed the respondents to choose the best and worst possible careers as endpoints on a 10 point scale. Forty-five additional careers were also included in the survey. Careers in teaching were generally rated low, with the exception of physical education and mathematics teaching. The respondent's race and educational aspirations were shown to be significant (0.05 level) with ratings of some science teaching careers. The job held by the respondent's parents was also significant in some cases. The most obvious result of this study was the verification that eighth grade students do not rate science teaching as a desirable career.

Summary

Care must be taken in summarizing the results of any set of disparate studies because of obvious differences in designs, subjects, treatment conditions, etc. Yet certain elements emerge that appear worthy of mention. It seems clear that there is a relationship between certain student characteristics such as field independence and such outcomes as achievement and problem solving ability. Further, there is a relationship between certain background factors such as family characteristics, school characteristics, and societal characteristics and student achievement in science. Science achievement is also related to aspects of teacher behaviors and strategies such as questioning approaches and wait time and to approaches that increase student engagement or time on task. Student engagement (which implies an intensity rather than a duration of experience) also may be a factor in situations involving hands-on activities or other direct experiences, both of which positively influence achievement. This also may be an underlying factor in the increased achievement found for small group interaction, whether in the laboratory or in the use of microcomputers. The development of a conceptual structure or framework during the instructional process also contributes to improve achievement. Finally, evidence continues to be presented which indicates a gender difference when students consider a science related career; this is a problem to which we must attend if we are to increase the number of females in science careers.

High School General Science

Introduction

Seven research reports related to high school general science are reported in the following sections: (1) Student Characteristics; (2) Classroom Behaviors; and (3) Curriculum.

Student Characteristics

Hafez (106) tested the relationship between students' cerebral lateralization for the Arabic language and their achievement in science. A secondary purpose was to investigate handedness as a factor in that relationship. The experiment, using dicholtic listening, was conducted in Saudi Arabia. A test consisting of eight introductory and 30 experimental trials of three pairs of monosyllabic Arabic words was administered to 280 male students in grade 11. The conclusions drawn were as follows: (1) Like other descriptive languages, the Arabic language was perceived and processed in the left cerebral hemisphere in the majority of the native speakers. (2) Achievement in science depends upon the organization of linguistic functions in the cerebral hemisphere and the corresponding pattern of language lateralization. (3) Left hemispheric lateralization of language furnishes a more adequate substrate for a higher level of achievement in science than does right hemispheric lateralization. (4) The degree of left hemispheric lateralization of language correlated positively with science achievement. (5) Handedness is a factor in the relationship between science achievement and language lateralization. (6) Right-handedness and left cerebral lateralization of language, together, were associated with a high level of neurological readiness for learning science. (7) Left-handedness and/or right hemispheric language can be viewed as distracting elements which interfere with achievement in science.

Classroom Behaviors

Hertz-Lararowitz, Baird, Webb, and Lazarowitz, (120) observed six junior high classes and one high school class in an attempt to assess the significance of student-student interaction (S-S-I) in the facilitation of learning. Each class was observed at least twice during the study period and all observations used the instantaneous sampling procedure. These observations were designed to investigate pupil interactive and non-interactive behaviors in the classroom in relation to structural dimensions of the classroom. The study determined that large percentages of the studied classes were teacher-centered. In this type of classroom, most of the student

behaviors were found to be either passive, non-interactive, or a student-student interaction. Forty-two percent of all behaviors observed were S-S-I. Only one-third of these, however, proved to be on-task. The authors also found that no significant difference in S-S-I occurred in classrooms because of varying discipline styles. Clearly the most significant part of the study did indicate that the mode of instruction affected the patterns of S-S-I. Social events did not differ among instructional modes, but cooperation and helping differed significantly. The authors stated that this would suggest that teachers could stimulate and channel many S-S-I to productive student interactions. They also suggested that teacher centrality be reduced, and student autonomy be increased to facilitate cooperation and increase helping type S-S-I.

Ogunniyi (203) attempted to identify and describe the nature of verbal behavior in 24 randomly selected science teachers. The teachers were selected from the Ibadan Local Government area of Oyo State, Nigeria. A modified version of Flanders' Interaction Analysis Categories was used by the author's team to categorize the observed interactions. The author found instruction to be teacher dominated, and that students were mostly passive. Most questions asked were factual in nature. This verbal pattern seemed to be identical across the three science areas: biology, chemistry, and physics. The author stated that some teachers who taught in this manner did so because of the style of the centralized examinations given to their students later. Ogunniyi stated that it is quite doubtful if just listenting, absorbing, and recording information can really develop higher levels of cognitive thought.

A study by McGarity and Butts (180) was designed to determine the relationship among teacher classroom management behavior, student engagement, and student achievement of middle and high school science students. These variables were investigated across varying levels of academic aptitude. Two week-long units were taught by 30 experienced science teachers. During this period of time teacher classroom management behavior, student achievement (n=570), student engagement (n=269), and student academic aptitude (n=649) were measured. Twelve selected management indicators from the Georgia Teachers Performance Assessment Indicators (TPAI) were used to measure teacher classroom management behaviors. Analyses showed that there was a significant relationship among all variables. Post hoc analysis showed that these results were consistent across levels of aptitude. Other relationships found were between student engagement and achievement, student aptitude and achievement, and student aptitude and engagement. Those particular management behaviors which were correlated with achievement and engagement were: identifies students who do not understand direction and helps them individually, maintains learner involvement in lessons, reinforces and encourages the efforts of learners to maintain involvement, attends to routine tasks, uses instructional time efficiently, provides feedback to learners about their behavior, manages disruptive behavior among learners.

Gan (94) sought to obtain insight into the pattern of relationships between students' achievement in science and study behavior variables. Surveyed were 17-year-olds in the science stream of two secondary schools in Kuala Lumpur. Sex differences were found.

Curriculum

A study by Kappraff (139) was to develop, field test, implement, and evaluate a high school general science enrichment program, incorporating creative hypotheses formation techniques (CHFTs) to promote the student's ability to solve science problems. The following CHFTs were taught and applied in each of six modules: brainstorming, work and picture analogy, personal analogy, checklist, verb modifiers, negatives, and synectics. All students who used the modules were able to apply some CHFTs to library-based research to reach solutions to the problems studied.

Reid (229) compared claims made by teachers about the 'readability' of worksheets and the actual 'readability' of the worksheets themselves. Questionnaires consisting of 31 questions were completed by 250 teachers from schools that were adequately equipped with laboratory facilities. The worksheets were analyzed using a microcomputer program (SMOG) that records the number of sentences, words, syllables and words with three-or-more syllables in each sample. Both Fry and Flesch measurements of readability indicated that the level of readability of the teacher-prepared worksheets was significantly lower (six months) than the reading age of the target population. Reid stated that the more able students are not being stretched by such practices. The author also stated that the readability formulas are of limited value because 80 percent of all teachers do not evaluate their work. Secondly, readability formulas have several weaknesses that make the formula suspect in terms of both validity and reliability. The author does state, however, that these readability formulas, if used judiciously by schools, could generate improved teacher-produced worksheets.

Summary

The investigations reported at this level do not provide enough similar studies to permit generalizations. The findings reported, however, regarding teacher behaviors and student achievement are similar to those previously reported. The Georgia Teachers Performance Assessment Indicators (TPAI) appear to be useful for identifying teacher variables related to student achievement.

High School Physical Science

Introduction

Four research reports are included related to high school physical science. Reports are categorized into the following sections: (1) Teaching Methods; (2) Testing Methods; and (3) Technology/Microcomputers.

Teaching Methods

McIntosh (183) investigated the effects of augmenting the learning of physical science rules by imaging prototypic examples of subordinate concepts. Three of the gas laws were taught to ninth grade students. Prior to the treatment, all students were classified as demonstrating either high or low imagery ability. Intact homogeneous classes were randomly assigned to either a treatment or a control group. Students in the treatment group were encouraged to create and draw images of a gas behaving in a way that would be congruent with one of the gas laws. Students in the control group were not encouraged to create images and were instructed to write pertinent information in their notebooks. Students in both groups were asked to complete a questionnaire attesting to their imagery utilization. The following conclusions were reached: (1) The ability to create images is advantageous for a situation requiring the recall of rules. (2) The actual use of imagery is advantageous for a situation requiring the recall of rules. (3) The treatment condition provided an advantageous situation for students demonstrating low imagery ability and/or imagery utilization.

Testing Methods

Using 273 high school students who were taking Introduction to Chemistry and Physics (ICP), Dunkelberger and Heikkinen (74) tested the influence on learning of the repeatable testing provision of the mastery learning model. Fifty-six students were assigned to both groups: (1) internally monitored-student verification of mastery through criterion-level attainment by repeatable testing; and (2) externally monitored - self-motivated mastery with single, non-repeatable test. The experiment followed the pretest/posttest control model and both groups were pretested before any differential treatment was administered to the experimental groups. The testing included the CAT (Cognitive Achievement Test), an attitude survey of science, and the Verbal Aptitude portion of the Delaware Educational Assessment Program. The internal achievement monitoring was

accomplished through computer generated repeatable tests upon which students must show 80 percent mastery before going on. The external achievement monitoring was also accomplished through computer generated non-repeatable tests from which students could identify problem areas to be studied before continuing to new material. Contrary to theoretical expectation, neither achievement nor attitude of the students was favorably influenced by repeatable testing. The authors did note that the externally-monitored students spent more time in the ICP area than did the internally-monitored students. This indicated that motivation to complete optional activities was high but in no way influenced achievement, because there was no long term measurable effects. The authors did not suggest that 'single-time testing' is an adequate substitute for retesting programs, but they did suggest that, with remedial guidance, students (internally monitored) are capable of studying and learning course objectives.

Hsu (129) constructed a pictorial physics test which would measure the degree to which ninth-grade students understand basic physics. It was proposed that the test would be used in Taiwan to assess, through pictorial means, the degree to which a student has attained a nonsyllogistic or intuitive understanding of physics. The pictorial instrument contained items in a stem picture and three/four choice pictures: one of which was true in relationship to the stem. Five-hundred-ninety students were randomly selected for the study. Students performed better on the pictorial test than on a verbal test. The higher the student's IQ level or the higher the student's science aptitude level, the better the performance was on the pictorial physics test. Students from urban areas showed better performance on the pictorial physics test than those in suburban or rural areas. However, there was no significant difference between suburban students and rural students. Male students had higher achievement scores than did female students. The practical advantages, reliability, and validity of the pictorial physics test indicated that it provided a potentially unique and useful tool to the junior high school physics teacher in Taiwan.

Technology/Microcomputers

Wise (312) compared the effects of alternative ways of using microcomputer laboratory simulations on the achievement and attitudes of high school physical science students. The instructional strategies compared were pre-laboratory simulation, post-laboratory simulation, and conventional laboratory instruction. Outcome data were collected on three classes of ninth grade physical science students (n=58). Students in each class worked on laboratory activities related to basic electrical circuits. The laboratory activities were keyed to instructional objectives which all students were working to achieve. Students in the simulation groups also interacted with microcomputer laboratory simulations either before or after related laboratory activities. The students worked on the

simulations as a class with the teacher operating the microcomputer and simulation programs. Both pre-laboratory and post-laboratory microcomputer simulation strategies resulted in higher student achievement than conventional laboratory instruction. This difference occurred on achievement above the knowledge level. While each of the instructional strategies employed in this investigation resulted in positive student attitudes, pre-laboratory simulation or conventional laboratory instruction produced the most positive attitudes. Higher aptitude level students out-achieved lower aptitude level students. The effects of the alternative instructional strategies were consistent across aptitude levels.

Summary

The number of investigations reported at this level do not provide enough similar studies to permit generalizations specific to the subject areas. Work reported focuses on improving achievement and provides suggestions for future research. The study by Dunkelberger and Heikkinen regarding repeated testing indicated findings that would not be expected from a theoretical position; replication of the study and analysis of the procedures used would be useful to aid further research.

High School Earth Science

Introduction

Three research reports related to high school earth science are reported. Reports are categorized into the following sections: (1) Student Characteristics; (2) Teaching Methods; and (3) Curriculum.

Student Characteristics

Daily attitude and achievement data were examined for groups of students formed on the basis of cognitive tendency, sex, and intelligence quotient by Monk (195) using a multiple-group single-intervention intensive time-series design. Data were examined to determine if the design could be used to detect differences between such groups, to determine if significant correlations existed between daily achievement and attitude measures within such groups, and to investigate the potential application of the design in the generation of models for daily group achievement. Data were collected from students of one eighth-grade earth science teacher (n=133) and one ninth-grade earth science teacher (n=103) for approximately 50 days. The intervention was a 25 day long unit on plate-tectonics.

Differences were found in the patterns of daily achievement and the overall levels of achievement for groups of students formed on the basis of cognitive tendency and IQ. No such differences were detected between sexes. No conclusive results were obtained in examining daily attitude data for group differences. In several cases there existed significant relationships between daily achievement and attitude group scores. Models were generated which explained up to 76 percent of the variance of achievement scores. Inconclusive results were obtained for attitudinal elements of this study.

Teaching Methods

Wiley (308) compared the degree of concrete and abstract geologic conceptual development on ninth grade male and female students in order to find if a difference existed in concept formation favoring the use of a single process-oriented field trip or normal classroom activity. Group One consisted of 20 students who experienced a field trip using a content-oriented guidebook. Group Two students used a process-oriented guidebook that differed from Group One in that the process-oriented guidebook posed questions regarding the topics at hand while the content-oriented guidebook gave information directly. The questions in the process-oriented guidebook were more inquiry oriented. Group Three was a control group having 28 members who were taken on a placebo field trip to a different location and who investigated different concepts in an unstructured manner. No significant ANOVA differences were found at the .05 level, however, MANOVA showed that group assignment (favoring process-oriented) is the most important factor in the development of concrete concepts that persist over time, while the order of concept revelation is most important in the development of abstract concepts that persist over time. This indicates that the style of writing used in a guidebook should be correlated to the level of learning outcomes desired.

Curriculum

Solarte (262) sought to develop and validate a general model of cognitive complexity that can be used to match the scientific structure of the subject matter to the learner's cognitive abilities. Data were gathered from 433 secondary school students enrolled in Regents' earth science classes in western New York on two major variables: science achievement and intellectual level. The science achievement data were collected by means of an earth science achievement test; and the intellectual level was measured by means of a Science Reasoning Task. The content was analyzed for Understanding Levels of Demand by means of a measurement procedure called Phi Omega Diagrams Test. The data analysis resulted in the following findings:

(1) There was significant positive correlation between the students' cognitive complexity and their Piagetian levels. (2) There was a significant negative correlation between the complexity of the content and its Understanding Levels of Demand.

Summary

The number of investigations reported for earth science do not permit clustering for analysis. Monk's study, which identified 76 percent of the variance related to student achievement, provides further indication that time series analysis can provide useful information for improving instruction.

High School Biology

Introduction

Thirty-eight research reports related to high school biology are reported. Reports are categorized into the following sections: (1) Student Characteristics; (2) Student Conceptions and Misconceptions; (3) Student Attitudes; (4) Teaching Methods; (5) Advanced Placement Courses; (6) Textbooks; (7) Curriculum; (8) Foreign; and (9) Technology and Microcomputers.

Student Characteristics

Jolly and Strawitz (138) investigated the consequences of teacher-student cognitive style matches and mismatches on student achievement in tenth grade biology. The Group Embedded Figures Test (GEFT) was administered to teachers in a large metropolitan school system in Louisiana. Five field dependent (FD) and five field independent (FI) teachers were identified. The GEFT was administered to their students; 241 FD and 175 FI students were identified. The testing for achievement on a prepared unit indicated that FI students achieved significantly higher than did FD students with both FI and FD teachers. Field dependent students scored highest with FI teachers, while FI students achieved equally well with both FI and FD teachers. One possible explanation could be that FI, but not FD, teachers used strategies that proved advantagous to the achievement of FD students. The authors also pointed out that an additional explanation could relate to the nature of the criterion measure and to the information-processing demands on many of the unit objectives. The findings suggest that FI students are able to learn certain types of abstract scientific material regardless of the cognitive style of their teacher. In contrast, FD students seem to need an FI teacher to

complement their own learning style. The fact that these differences in learning style need not result in learning differences is significant and encouraging.

Sherris and Kahle (249) investigated the effects on achievement of concept-related instruction organization and locus of control. Two five-week instructional treatments were developed, one which explicitly stressed concept relationships and one which did not. Five hundred and forty-one subjects at six Indiana high schools were involved in the study. Analyses of posttest and six-week retention test scores showed no significant treatment effect. Analyses of variance of test scores with locus of control as the independent variable resulted in highly significant differences. Subjects with an internal locus of control achieved more than did externally oriented subjects. A statistically significant treatment/locus of control interaction effect for retention test scores was also found. Externally oriented subjects who were exposed to the concept-related treatment generally retained more than those subjects in the comparison group. Internally oriented subjects retained about the same amount of information regardless of treatment group. When the male and female subjects were analyzed separately, the interaction effect appeared greater for females than for males.

Texley and Norman (287) developed an instrument to assess the logical reasoning capacity of adolescents in the content area of environmental science. Characterized as a group test, the instrument consisted of five concrete experiences related to environmental concepts, to which pencil-and-paper responses were made. The instrument was validated through (1) logical analysis of items from the standpoint of Piagetian theory, (2) correlation with clinical interviews and group test results in physical science, and (3) factor analysis. The results indicated an acceptable level of validity; however, subjects performed well below the theoretical levels predicted by theory. The results also suggested that reasoning ability in environmental science was lower than in areas associated with the physical concepts usually tested. The data suggested the presence of a horizontal decalage, or time lag, between the development of logical reasoning skills in areas of familiarity, such as physical science, and areas of content less familiar to the subject or those in which logical structures may be less frequently used in the development of evaluation instruments.

Student Conceptions and Misconceptions

Mintzes and Arnandin (192) reviewed 68 studies on conceptual development in the biological sciences. Each study was classified by type of concept(s) under investigation and by the research method employed. When classified by concepts, five groups were identified. They included (1) life (living versus nonliving) and death; (2) plants and animals; (3) the human body; (4) biological continuity; and (5)

other biological phenomena. These studies indicated that conventional teaching approaches often leave students' preconceptions of biological concepts undisturbed. Therefore, several researchers have directed their efforts to create conditions under which students are likely to exchange an old concept for a new one. One model suggests that conceptual change begins with dissatisfaction, and then change occurs when the concept possesses more intelligibility, plausibility, and fruitfulness than the old concept.

Grade ten high school students' understanding of the mechanisms of inheritance following a course of instruction was explored by Hackling and Treagust (105). A partially standardized interview procedure was developed, based on inheritance concepts and propositions which were considered necessary for an understanding of inheritance. Concepts and propositions that were understood, not understood, or misunderstood were identified.

A study by Abimbola (2) described alternative conceptions related to human respiration held by Nigerian Form Four students. Twenty-seven 15-to-21-year-old students from Osogbo, Oyo State, Nigeria took part in the study. The students' regular biology teacher taught the three 40-minute units on human respiration using a lecture method. The students' conceptions of human respiration were assessed in individual interviews before and after instruction. Both the instruction and the interviews were audio recorded. The students' alternative conceptions were identified and categorized. Qualitative comparisons were made among the conceptions before and after instruction and the stable alternative conceptions were identified. The pre-instructional, post-instructional and stable alternative conceptions identified were in the following areas: (a) composition of air; (b) the relationship between human respiration and digestion; (c) the relationship between human respiration and blood circulation; (d) the temperature of enclosed surfaces; and (e) breathing through parts of the body other than the nose and the mouth. Explanations were offered for some of the alternative conceptions in terms of the instruction, the students' culture (including their mother tongue) and the Nigerian climate.

Student Attitudes

Rideng and Schibeci (235) developed and validated a test to measure biology related attitudes (TOBRA) for students in grades 10-12 in Indonesia. TOBRA's conceptual structure was examined through the use of latent partition analysis. The authors stated that the test could be used by educators to monitor the effectiveness of those teaching methods aimed at attitudinal objectives. The test is structured so that teachers could use different subscales to evaluate different biology teaching methods.

Talton (281) examined the relationship of classroom environment to attitudes toward science and achievement in science among 1560 students enrolled in 70 tenth grade biology classes. Instruments were administered at three times during the school year to measure student attitudes toward science and the classroom environment. The classroom environment measures examined six areas: emotional climate of the science classroom, science curriculum, physical environment of the science classroom, and friends' attitudes toward science. Student achievement in science was measured by teacher-reported semester grades. The major findings of the study were as follows: (1) Student attitudes toward the classroom environment predicted between 56 to 61 percent of the variance in attitudes toward science. (2) Student attitudes toward the classroom environment predicted between 5 to 14 percent of the variance in achievement science. (3) Student attitudes toward science and attitudes toward the classroom environment predicted between 8 and 18 percent of the variance in achievement in science. (4) There was a weak positive relationship between attitudes toward science and achievement in science. (5) Past attitudes toward science play a role in relating attitudes toward the classroom environment to present attitudes toward science. (6) Data analyses using Lisrel V indicated the possibility of a causal relationship between attitudes toward classroom environment and attitudes toward science.

Teaching Methods

Advance Organizers

Mika (189) investigated the efficacy of a game advance organizer on improving the achievement of formal and concrete learners in tenth grade biology classes studying the Mendelian genetic principles of segregation and independent assortment. The students (n=109) came from two high schools in eastern Massachusetts. Prior to the treatment, each student was identified as either a concrete or formal learner by using the Longeot test. The treatment began with each student receiving a programmed lesson on basic genetic terminology. Experimental groups received a game advance organizer, The Yockie Mating Game (YMG). The control group viewed two filmstrips on genetic engineering. Each student, after either playing the YMG or viewing the filmstrips, completed two programmed lessons on monohybrid and dihybrid crosses. After completion of the programmed lessons, all students received a set of ten genetics problems with the control group receiving an additional ten genetics problems. The genetics problems were followed by both treatment groups receiving a Genetics Problem-Solving Test (GPST). After a period of seven weeks, all students in the study were retested with the GPST. The experimental group scored significantly higher on the GPST than the control group within one school. However, no significant differences were observed at the second school. Concrete learners, regardless of treatment,

scored significantly lower on a genetics problem-solving test than did formal learners, and there were no significant differences between males and females in their ability to solve Mendelian genetics problems regardless of treatment. The analysis of the GPST retest scores showed the same results.

Concept Mapping

Carter (44) investigated the effects of specific learning heuristics on the conceptual learning of biology by black high school students. The subjects were ninth and tenth grade introductory biology students in a Midwestern, urban area. The two treatments, concept mapping/Vee and outlining, were randomly assigned to intact classes. The instructional materials consisted of four individualized introductory biology units in a study guide format. The treatment groups used study guides which either introduced the learning strategy, concept mapping/Vee, or outlining during the experimental period.

Grouping

Brooks (36) conducted a study to describe the influences on secondary laboratory teachers' grouping decisions in a naturally occurring secondary school setting. A naturalistic approach was taken with stimulated recall and ethnography serving as tools for data collection. Two homemaking foods teachers and two biology teachers were the subjects of the study. Audiotaped recordings of homemaking classes and field notes recorded in the biology labs served as stimuli for unstructured interviews with the subjects. Additional structured interviews of the subjects plus teachers from other academic areas provided comparisons and contrasts of grouping practices. The analysis suggested that six factors were most influential on teachers' grouping decisions. These factors were labeled as task demands, management demands, student task approach, work habits, student ability, and social interaction skills. Biology teachers' decisions appeared to be driven by task demands, followed by management demands, task approach, work habits, ability, and social interaction. A tentative explanation is that departmental standards and the traditional image of science created the importance of task demands with the other factors being necessary to achieve them.

Games

A study by Dechow (66) sought answers to the following questions: Would high school students playing a game technique called the teams-games-tournaments have greater academic achievement in a high school biology course than students in traditional classrooms? Would high school students in TGT classes have greater retention of

knowledge? Would high school students in TGT classes have more positive attitudes toward biology? Would high school students like TGT better as a means for studying chapter material? Eight biology classes were involved in the seven-week treatment period. Analysis of variance was used to compare control and experimental groups for pretest, posttest and delayed posttest cognitive knowledge, and pretest, posttest attitudes. TGT had no significant effect on the biology achievement scores or attitudes towards biology.

The purpose of a study by Spraggins (269) was to analyze data resulting from two methods of instruction used in a high school biology course in order to determine the outcomes of student achievement and student retention. Students were assigned randomly to experimental and control groups within each of four biology classes. The experimental group played simulation games introducing the current lesson and was assigned worksheets related to a topic previously covered. The control group played simulation games pertaining to a past lesson and was assigned worksheets introducing the current lesson. The experiment was conducted at three intervals during the school year utilizing the simulation games, Geologic Time Chart, The Cell Game, and Blood Flow. Four instruments were developed to test immediate achievement and long-term retention. Students who were taught by the simulation games had achievement and retention scores comparable to the scores of students who were taught using worksheets. A significant three-way interaction of treatment, ability, and sex was found. Low ability females utilizing simulation games had higher retention scores than did low ability females utilizing worksheets. Low ability males utilizing worksheets had higher scores on retention than did low ability males utilizing simulation games. It was concluded that simulation games may be as effective in teaching certain biological topics as the more traditional worksheet method. Simulation games may be more effective in teaching low ability females.

Inquiry

Awodi (19) compared achievement in biology by Nigerian secondary school students (tenth grade) when taught either by the inquiry method or the traditional (lecture) method. A teacher training package based upon Biology Teacher's Handbook (2nd Ed. 1970) was developed by Awodi and used to train inquiry group teachers during a workshop. Results showed that students in the inquiry group attained a significantly higher level of achievement than did students in the traditional group.

Kuhn's model of the structure of scientific revolutions, Popper's hypothetic-deductive model of science, and Lakatos's methodology of competing research programs were applied to a historical episode in biology by Oldhan and Brouwer (205). Each of these three models offers a different explanatory system for the development, neglect,

and eventual acceptance of Mendel's paradigm of inheritance. The authors concluded that both rational and nonrational criteria play an important role during times of crisis in science, when different research programs compete for acceptance. It was suggested that Kuhn's model, emphasizing the nonrational basis of science, and Popper's model, emphasizing the rational basis of science, can be used fruitfully in high school science courses.

Lederman (161) tested the validity of the prevalent assumption that a teacher's understanding of the nature of science is related to changes in the conceptions of his/her students, and identified the classroom dimensions significantly related to changes in students conceptions. Pretests and posttests of the "Nature of Scientific Knowledge Scale" were administered to 18 biology classes. The study also included three intensive qualitative field observations of these same classes. Results of the study indicated that the teachers' concept of the nature of science was not significantly related to any changes in student conceptions of science. There did seem to be a set of basic characteristics present in classrooms where students exhibited the largest conceptual changes. For example, problem-solving and frequent inquiry-oriented questioning typified these classrooms. Students in these classes seemed to be more attentive and exhibited more participation.

Advanced Placement Courses

Carrick (42) investigated the background of Advanced Level Biology teachers, examining their teaching situations, views of the nature of science, and aims for Advanced Level teaching in Great Britain. Among the findings reported were those indicating little concern to foster a deeper appreciation of scientific processes and concern with low-level rather than higher-order cognitive skills.

Some aspects of the selection and teaching of options of Great Britain's Joint Matriculation Board's Advanced Level Biology syllabus were investigated by Carrick (43) by means of a questionnaire. The teachers' opinions of the options and their aims in teaching them were considered. Options seemed to be regarded favorably by most of the teachers.

Mercurio, Lambert and Oesterle (187) reported that the Syracuse University program "Project Advance" was equally successful in determining academic achievement as the Advanced Placement Program (AP) of the College Entrance Examination Board. Students taking part in the study had successfully completed Project Advance (n=60) with at least a C prior to taking the AP examination. Ninety-six percent of Project Advance students with a final letter grade of B or above earned at least a 3 on the AP examination. Overall, 88.4 percent of the Project Advance students taking part in the study earned at least a 3 as compared to the National average of 75.6 percent.

Warren (300) reported that highly motivated ninth and tenth graders can complete the equivalent of two years of biology in one year even without a chemistry background. Student selection for this course was highly competitive and occurred over a two year period. Since passing the Advanced Placement (AP) exam seemed to be more important to some students than the knowledge gained, considerable class time was used in preparation for the exam. During the period reported, 1979-82, 98.4 percent of the accelerated students qualified nationally (score of 3) with 34.9 percent of them obtaining the maximum score of 5. These scores do not differ significantly from the scores obtained by the students taking two years of biology at The Bishop's School. The author felt that the scores indicated a signficant degree of success with these accelerated students. The scores were also significantly higher than the national average when considering the maximum scores of 4 and 5. The author felt that the data supported this type of class and that capable students must be given the opportunity to study and learn at a demanding pace.

Gayford (98) discussed concepts needed to understand plant-water relations and results of a study designed to examine the understanding of these concepts by students preparing for A-level examinations in Great Britain. The study focused on students who had learned the topic using the old terminology compared with students adopting the new suggested terms.

Textbooks

Wright and Spiegel (320) designed a study to seek answers to the following questions: (1) Are biology teachers able to accurately judge the readability level of instructional material? (2) What factors do they consider when judging readability level? (3) Do biology teachers consider differences in students' reading ability when choosing reading material for them to use? A questionnaire survey of 662 high school biology teachers indicated that the majority of biology teachers did attempt to match students with appropriate material. They were aware of factors that contribute to the difficulty of a reading selection such as sentence structure, vocabulary, nature of the topic, concept load, and concept depth. In addition, they also considered student factors such as ability background knowledge, future plans, and affective concerns.

Cho and Kahle (49) reported results of a study of the relationship between concept emphasis in high school biology textbooks and achievement levels. Analyses of student responses to biological items on the 1977 National Assessment of Educational Progress's survey of science showed a direct, linear relationship between achievement level and concept emphasis in biology textbooks. A comparison between biology textbooks, published a decade apart, indicated significant changes in the degree of emphasis placed on ten commonly accepted

conceptual areas. Closer examination revealed that change in the amount of emphasis in one conceptual area, Growth and Development, was responsible for the significant difference found. Generally, the recommendations of the biology project were not reflected in the newer textbooks.

Stone (275) examined 12 history and biology textbooks from 1905-1975 to trace the trends in conservation and ecology instruction. The results fell into five categories. First, the topics changed: "conservation" in biology textbooks became "ecology" after 1960. Second, the level of abstraction changed from concrete to abstract in biology textbooks. Third, in both subjects the values became less explicit. Fourth, responsibility for behavior changed from individual to cooperative to dependent on scientists and government. Finally, a major shift in perspective took place in biology textbooks after 1960. This "ecocentric" perspective has been partly retained in some books to the present, but others have retreated from the viewpoint and its implications. The 1960's shift is attributed to a new emphasis on evolution and other topics from the discipline of biology. All history textbooks have been anthropocentric.

A longitudinal review of the coverage of evolution in high school biology textbooks was conducted by Skoog (253). His research determined the coverage given to 44 topics related to the study of evolution in 105 high school biology textbooks published between 1900-1983. The textbooks were selected on the basis of their availability and authorship. Efforts were made to analyze textbooks that had been revised over an extended period of time so that changes such as deletions or word changes, from one edition to the next, could be noted. Word counts were used for comparisons and indicators of trends. Factors such as trends in popular textbooks; trends in other textbooks; trends in BSCS textbooks; coverage of evolution in first editions; coverage of creationism; and chapter titles and placement were considered. Data from this study indicated there has been a definite erosion in the coverage of evolution in all high school biology textbooks since the 1960's. Because textbooks have much influence on what is taught, Skoog inferred that high school students are learning less about evolution now than in the 1960's and 1970's.

Woodward and Elliot, (317) surveyed research on the treatment of evolution in high school biology textbooks to determine if educators have a choice in selecting textbooks with respect to evolution. They found that between 1920 and 1960 the majority of biology textbooks inadequately covered evolution and Darwin, or excluded this material. The analysis of 15 books revealed four patterns of publisher response varying from extensive and uncompromising treatments (six books) to complete avoidance of the subject (two books). Thus, it does appear that educators do have a wide choice when dealing with the concepts of evolution.

Barrow and Bitner (24) undertook an examination of six commonly utilized tenth grade biology textbooks that had a 1980 or newer copyright date to determine their cancer education content. Adequate

cancer education content was based on their coverage of three broad categories: (1) scientific aspects; (2) clinical aspects; and (3) psycho-social aspects of cancer. Although cancer coverage varied from textbook to textbook, the authors concluded that the overall coverage was inadequate. Biology teachers need to supplement their books by providing additional information about cancer.

Twenty-two high school biology textbooks published between 1963 and 1983 were analyzed by Rosenthal (239) for their treatment of social issues. Textbooks were selected from among those used most frequently by teachers and/or having the highest sales. The textbooks were read in random order and the amount of space, to the nearest tenth of a page, devoted to each social issue was determined. It was found that the attention devoted to social issues decreased between 1963 and 1983.

Gardner (95) examined the evolution controversy in the professional educational literature published between 1980 and 1981 and discussed the controversy in terms of Kuhn's Structure of Scientific Revolutions. The study showed that once an idea has won acceptance in the scientific community, it must undergo a second testing to gain acceptance by the general public. Based on this study, it appears that the more a scientific idea conflicts with the fundamental values of individuals and groups within the society, the greater the chance of conflict. The study also showed that the criteria and mechanisms for acceptance of new ideas in the larger society are different from the criteria and mechanisms for acceptance in the scientific community.

Curriculum

BSCS

Shymansky (251) examined Biological Sciences Curriculum Study (BSCS) programs and how they compared to each other and to other science programs. Also examined were how various student groups performed in new curricula as compared with student performance in a traditional curriculum. The study involved 302 studies which spanned a total of 25 years of research. The studies indicated student performance in each of several new programs was better than in traditional courses across all performance measures (achievement, student attitudes, process skills, and analytic skills). This effect was most marked for BSCS biology. Public support of science education decreased progressively during the 1970's and hit rock bottom in early 1982. The general sentiment was that the new science programs were a waste of money and were the cause of the decline in student scores in science. Shymansky suggests that the discarding of the new science curricula contributed to the crisis in science education.

Relation to Health Education

Hickman (121) examined the commonalities in goals and objectives that education in science and health now share and summarized the major convergences and divergences that characterize their histories. A definitional framework for curricular synthesis was provided with two specific examples--alcoholism and environmental threats to health. Some steps that can be taken to establish a workable synthesis, not only in science and health, but in the total school curriculum as well, were suggested.

Biosocial Issues

While (307) conducted a study to determine the relationship between participation in National Science Foundation (NSF) Pre-College Teacher Development (PTDS) Projects on Human Genetics and Bioethical Decision-Making held at Ball State University and classroom implementation of the Desired Biology Program described by Project Synthesis. Both projects focused on goals which emphasize human biology, biosocial concerns, and an understanding of the role that attitudes, values, and human needs exert in making decisions. The researcher employed an ex post facto criterion group design. Two groups of life science teachers, matched by gender, teaching experience, and location were selected for study. The criterion group participated in ISF-PTDS Projects; the control group lacked NSF-PTDS Project experience. A questionnaire was constructed to collect data. Teachers in both groups indicated they stressed the use of biological concepts to interpret human concerns. Groups differed in the amount of time allocated to human topics during the study of genetics. Although both groups of teachers devoted similar amounts of time to studying genetics, teachers in the criterion group tended to delete non-human topics and incorporate human topics to exemplify genetic principles. Teachers in the criterion group integrated significantly more bioethics into their biology and life science programs.

Foreign Countries

Friedler and Tamir (91) compared the intended, perceived, implemented, and achieved curriculum of high school biology classes in Israel. The intended curriculum was identified by analyzing commonly used laboratory manuals. The perceived curriculum was measured by collecting views of teachers and students on the importance and practice of educational objectives associated with learning in the laboratory. The implemented curriculum was assessed by structured and non-structured observations. The achieved curriculum was assessed by analysis of a large sample of practical laboratory matriculation

examination papers. The findings indicated too little consideration of scientific inquiry in textbooks and in classes. Deficient mastery of inquiry skills was also indicated by students' answers to the laboratory examination. To alleviate this problem a learning module to enhance students' understanding of the processes associated with planning investigations was developed and field tested with a number of 12th grade classes. The authors further recommend incorporation of pre- and post-laboratory discussions to enhance achievement in science laboratory activities.

Adeniyi (4) conducted an analysis of the relationship among intended curriculum, in-use curriculum, and students' cognitive structure associated with an ecology unit in selected Nigerian High School biology classes. Differences were found between the two curricula with respect to philisophy and approach to science teaching, use of specific teaching activities, conceptual/propositional content, and content sequencing. This was attributed to different conceptualizations of science teaching, the teacher's failure to grasp the intended instructional strategy, and their limited understanding of certain concepts. Less than 50 percent of the students acquired most of the considered content.

Papenfus (212) conducted an analysis of high school biology curriculum content in South African schools. From this a model was developed. The elements in this model are to be used as curriculum principles to be applied in curriculum construction. Didactic guidelines in a curriculum are considered and the role of learning opportunities is stressed. The results of the situation analysis and others based on a literature study have been used to describe curriculum criteria for implementation in curriculum construction.

A study to compare the outcomes achieved by students taking biology courses based on either the West African Examination Council (WAEC) revised biology syllabus or the WAEC developed alternative syllabus and to look at some of the factors that may be associated with these outcomes was conducted by Iyiola and Wilkinson (136). A criterion-referenced biology achievement test was given to 340 students from 89 secondary schools. The test items covered areas that were common to both the alternative and the revised WAEC course of study and placed emphasis upon the testing of a wide range of cognitive abilities. A students' and teachers' opinion questionnaire was also used. Iyiola and Wilkinson found that the mean score of the alternative students on the criterion-referenced test was significantly superior to that of the revised WAEC students. From an analysis of the teachers' responses to the questionnaire, it was found that a significant number of the alternative group teachers appeared to be more aware of the social and educational significance of biology.

An investigation by Waugh (302) had three purposes: (1) to document any immediate and continuing benefits associated with the use of microcomputer-administered diagnostic testing; (2) to determine what type of student might benefit most from microcomputer administered diagnostic testing; and (3) to document the feasibility of microcomputer-administered diagnostic testing. The subjects of the study were 68 private school students enrolled in a biology course based on the BSCS (Blue Version) text, Biological Science--A Molecular Approach. A random half of the students received behaviorally-stated performance objectives while the remaining half received behaviorally-stated performance objectives in conjunction with microcomputer-administered diagnostic testing. The following conclusions were drawn: (1) Testing can positively influence short term but not long term biology achievement. (2) Students of varying levels of achievement motivation did not exhibit differences in biology achievement. (3) The effects of testing were consistent across levels of achievement motivation. (4) Due to the low cost of microcomputers and the relative ease of management, microcomputers are feasible agents for the administration of diagnostic testing. (5) Students liked behaviorally-stated performance objectives, and they believed that the objectives helped them study. (6) Students did not believe learning to use computers was too difficult, and they were interested in learning to program.

Spector (267) conducted an exploratory study which focused on teachers' responses to the demand for role change brought about by the implementation of a new course. Two procedures used to gather data were participant observation and open-ended interviews. Role theory, symbolic interaction, and schools as organizations were used as the frameworks for data analysis in this discursive qualitative study. The data reported describe the teachers' perceptions of factors influencing their willingness to change behaviors in order to comply with the role demands of the innovation. Hypotheses grounded in the data were generated and tied together into a theory which is illustrated by a structural model. The model shows interrelationships of factors influencing the teachers to change roles at the time of initiation of the new course through the ultimate incorporation of the innovation.

Ali (10) attempted to determine the effects of using laboratory photomicrography as a motivational technique in the study of microbiology in Nigerian secondary schools. This was done by comparing the posttest scores and questionnaire responses made by three equal groups of randomly sampled and assigned students taught the same content by lectures and photomicrography used as an adjunct to the laboratory, lectures, and laboratory activities and lectures alone. Each group was taught by a different teacher. Students taught by lectures with photomicrography activities achieved the highest posttest mean score and expressed the opinion that they were highly

motivated by this teaching method. Students taught by lectures with laboratory activities achieved lower mean posttest score and expressed the opinion that they were only fairly motivated by this teaching approach. Students taught by lectures alone achieved the lowest mean posttest score and expressed the opinion that they were least motivated.

Summary

The amount of research conducted related to the teaching of biology continues to be extensive; most of the findings continue to build on previous research and report expected results. More research is being completed on cognitive learning, misconceptions (alternative concepts), instructional materials and learning styles; results of these studies indicate the need for modification of instructional materials and instruction. A meta-analysis study is reported by Shymansky regarding the use of BSCS; achievement attitudes, process skills, and analytic skills in BSCS classes were higher than in comparative courses. Several foreign studies are also reported.

High School Chemistry

Introduction

Seventeen research reports related to high school chemistry are reported. Reports are categorized into the following sections: (1) Student Characteristics; (2) Student Conceptions and Misconceptions; (3) Teaching Methods; (4) Testing; (5) Curriculum; (6) Problem Solving; and (7) Technology/Microcomputers.

Student Characteristics

Maiman (175) attempted to assess the minimum Piagetian cognitive abilities required for understanding of selected chemistry concepts taught to twelfth grade male science students in Saudi Arabia. The study was performed with 209 twelfth grade male students in Saudi Arabia. Data for the study were collected by two instruments: Chemistry Concept Test and The Logical Reasoning Test. (1) Out of 16 concepts tested, 12.5 percent were found to require non-formal thought; whereas 87.5 percent of the concepts tested required the students to be formal thinkers in order to understand the concepts the way they were presented to them. (2) Sixty-seven and one-half percent

of the students were found to be non-formal thinkers. Maiman recommended that the present chemistry curriculum taught to twelfth grade Saudi students be reevaluated in order to fit the cognitive level of the learner. He also recommended a special training of the high school chemistry teachers in Piagetian theory and its applications in the teaching-learning process.

A study reported by Cook (58) wsa to investigate the effect of a remedial mathematics program on chemistry achievement, mathematics achievement, and attitude toward science of beginning high-school chemistry students. The study was conducted over a period of two academic years, involving 126 students from nine CHEM Study classes with two teachers at two high schools in New Jersey. At the start of the experiment, all students were tested for cognitive development, attitude toward science, and mathematics ability. The students were posttested after one semester for mathematics achievement, chemistry achievement, and attitude toward science. The results showed that the developed Chemistry Mathematic Pretest (CMP) was both reliable and valid. The remedial program had no significant effect on chemistry achievement. However, mathematics achievement was significantly improved for the females in the experimental group, while the attitude of the males in the experimental group decreased.

Student Conceptions and Misconceptions

Yarroch (322) examined the instruction, by four high school teachers, on introductory chemical equation balancing and compared the concent specific knowledge of the instruction with knowledge that a sample of their students possessed after the instruction. Unaltered classroom instruction on chemical equation balancing was observed and tape-recorded. Students who received the instruction were given a written examination to determine their ability to balance simple two element, one compound chemical equations. The results indicated that while all of the students learned to balance simple chemical equations, they did so at the syntactic knowledge level. Instruction on this content was observed to be predominantly at the syntactic level and the students had attained very little of the high level chemical knowledge associated with the equations.

Teaching Methods

Peabody (213) conducted a study to determine whether an instructional unit which made use of specific concrete examples, analogies, and the physical manipulation of stick and ball models increased achievement on a test of chemical bonding. The sample consisted of chemistry classes from four Arizona high schools. The control and experimental classes were assigned randomly and a pretest was administered. A five-day instructional sequence for the

experimental group utilized specific concrete examples, analogies, and the physical manipulation of stick and ball models. The five-day instructional sequence for the control group was based solely on information given in the text. A posttest was administered to both groups upon completion of the instructional sequence. The concrete instructional procedure significantly increased the achievement of students in the experimental group. Both transitional and formal thinkers in the experimental group significantly outperformed their counterparts in the control group. Formal thinkers performed significantly better than transitional thinkers when comparing stages within the experimental group. No significant differences were found when comparing achievement of males and females.

Lehman, Koran and Koran (163) explored the effects on learning of: (1) structural modifications to the periodic table, (2) the location of a periodic table within instructional materials, and (3) the presence of a two-page schema showing relationships between the topics explained in the written materials and the periodic table. One hundred and sixty high school students were randomly assigned to one of eight treatments. A 28-item posttest consisting of multiple choice and constructed answer items was designed to measure the subjects' ability to use their periodic tables to obtain factual information and to solve qualitative chemistry problems. Subjects with minimal experience with the period table, and those who received the table with added visual data performed significantly better than subjects who received the other two tables. For subjects familiar with the periodic table, significant vocabulary X table and vocabulary X location interactions were detected. Subjects high in verbal comprehension tended to take advantage of the modified tables, while those low in verbal comprehension processed the traditional table with less information most effectively. These latter students also benefitted more from having the periodic table alongside their written materials.

Coffey (52) investigated and compared three methods of remediating high school chemistry, as part of Bloom's mastery learning system. The three methods of remediation were used by four high school teachers who each taught three classes of Regents level chemistry. A different strategy was used to remediate each class for each of three different chemistry units. The strategies were rotated so that each was used by all the classes and in all the units. The sample tested consisted of 276 students, divided one-half in suburban schools and one-half in a large urban school. Unit tests and summative tests were based on the New York State Regents questions. The results showed that a greater proportion of students attained mastery of high school chemistry concepts in the groups that received more intensive remediation. The mean on the retention tests for the teacher-tutored strategy group was also significantly higher than the mean of the group who experienced the least help.

Raizada (223) examined chemistry instruction from a perspective based primarily on John Ziman's communal knowledge model. Several grade 10, 11, and 12 chemistry lessons by three different teachers at three different schools were observed and audiotaped. Data were examined to demonstrate the occurrence of specific pedagogic tactics embodied in teacher utterances. Tactics reflected concerns for: 91) consensuality of their discourse; (2) consensibility of utterances; (3) commonality of the frame of reference; and (4) the commensurability of the subject.

Seddon and Shubber (246) selected 120 boys ages 15-16 years at random from all science courses in one senior high school in Bahraini to investigate the use of a teaching method based on the use of overhead projection transparencies containing a sequence of diagrams to represent a three-dimensional structure at different stages during a rotation. When the diagrams were exposed one at a time, or were monochrome, there was no significant learning as measured by test scores. However, when the transparencies contained multi-colored diagrams which were exposed simultaneously or individually in a cumulative manner, there was significant learning.

Testing

Cassels and Johnstone (45) investigated the effects of varying language in a multiple-choice question chemistry exam. Matched questions testing the same concepts but using different words were designed and organized in two tests. The tests were administered to two groups of pupils (n=3600) age 16 in each of three successive years. Results indicated that the substitution of words (in key positions) by simpler words brought an improvement in performance. The removal of negatives in test questions, in general, seems to improve the performance. Substituting wordy questions with shorter questions written in shorter sentences also improved performance. However, forming the question in passive or active voice seemed to have litle effect.

To study the effects of changes in question structure and sequence on performance in a multiple-choice chemistry test, Hodson (124, 125) administered 5 tests of 50 multiple-choice questions from the Joint Matriculation Board '0' level chemistry examination to students from six single sex grammar schools. The students were selected randomly and were in their fifth year of school. The questions were arranged randomly for one test form, easy-to-hard sequence (E-H) for another form, and a hard-to-easy (H-E) sequence was used for another form. Random question sequence but reversed answer position and reduced answer option were the two other test forms used. One finding noted that there was virtually no change in test reliability by reducing the number of answer options. Students performed a little better on the E-H sequence questions. In general, the study showed that there was nothing to be gained by expending time and energy on careful item sequencing.

Curriculum

The purposes of a study by Durr (75) were to: (1) analyze concepts for cognitive level of demand in two instructional units of the New York State Regents Chemistry Course of Study; (2) determine the extent to which the analysis could predict the Piagetian cognitive level required for concrete and formal operational students to understand the concrete and formal concepts analyzed; and (3) test suggested guidelines for determining cognitive level of demand of concepts in a chemistry curriculum. Guidelines were used to estimate the cognitive level of demand of major concepts and corresponding test items in instructional units on Acids and Bases and Chemical Equilibrium. Piagetian cognitive levels of 25 students enrolled in chemistry classes of four high schools in upstate New York were assessed. The major findings were as follows: (1) The cognitive level of demand of a majority of the concepts essential to a coherent understanding of Acids and Bases and Chemical Equilibrium content required formal reasoning patterns for comprehension. The predicted cognitive levels of demand of 29 percent of the test items on Acids and Bases and 40 percent of the Chemical Equilibrium unit items were confirmed. (2) Student cognitive level was significantly and positively correlated with overall unit test scores and with percent success on test items. (3) Schools were a significant factor in influencing student performance on unit tests. (4) A larger number of males than females were enrolled in chemistry classes, and a higher proportion of males than females was assessed at the formal operational cognitive level. Sex, however, was not a significant factor in influencing performance on unit tests.

A study by Ilogu (131) attempted to develop and validate an instrument that reflects the various types of learning encountered in the Introductory Chemistry laboratory. Initially, a table was constructed with one dimension consisting of seven content categories common to the Intro-Chemistry laboratory. The other dimension comprised different task categories the student was expected to demonstrate as an indication of successful completion of the laboratory requirement: Planning and Design, Performance, and Analysis and Interpretation. These categories reflected the instructional objectives of the lab activities. A jury verified the content and task levels of each item. Fifty items were administered to 626 high school and college students. Each participant also completed a questionnaire that probed his/her science background and career plans. Three research hypotheses containing these variables were formulated to support construct validity.

Ingle (132), assisted by E. H. Coulson and six teachers, undertook an inquiry to assess the need for a revision and to work out the guidelines for the Nuffield Chemistry currently being taught. Discussions were held on different aspects of Nuffield Chemistry with chemistry teachers and students, advisors, inspectors, and others. Follow-up questionnaires were sent to teachers in some 200 schools,

all of whom had experience in teaching the Nuffield Chemistry. About 20 schools whose teachers had replied to the questionnaire were visited for more detailed discussions. Findings from the discussions and questionnaires provided a wealth of information on how the student and teacher curriculum materials might be improved and made more effective. Some major changes made were: simplifications of package and drastic reduction of the number of publications to make them easier to handle; an alternative Stage II which had a completely different sequence of topics with easier ideas dealt with first and difficult ones later; production of a "Handbook for Pupils;" care in use of language; more use of color; more guidance for pupils in Experiment Sheets; use of work objectives throughout course; and mathematical notes in Teacher's Guide.

Problem Solving

Raines investigated differences in student recognition of problem similarity in high school chemistry, the relation of problem-similarity recognition to problem-solving success, and improvement in problem-solving success subsequent to consideration of problem similarity. Tests developed for this study were used to measure initial problem-solving success, problem-similarity recognition using a four-point context-to-structure scale, and final problem-solving success. Analyses of the data indicated that the most successful problem solvers differed from the moderately successful and the least successful problem solvers in their tendency to recognize problem similarity according to structure rather than context. Additionally, the most successful as well as the least successful problem solvers improved in problem-solving success subsequent to their consideration of problem similarity.

Gabel and Sherwood (92) attempted to determine which skills and concepts students have that are prerequisites for solving mole problems through the use of analog tasks. Two analogous tests with four forms of each were prepared that corresponded to a conventional mole test. The analogs used were oranges and granules of sugar. Slight variations between test items on various forms permitted comparisons that would indicate specific conceptual and mathematical difficulties that students might have in solving mole problems. Different forms of the two tests were randomly assigned to 332 high school chemistry students of five teachers in four schools in central Indiana. Comparisons of total test score, subtest scores, and the number of students answering an item correctly resulted in the following conclusions: (1) the size of the object makes no difference in the problem difficulty; (2) students understand the concepts of mass, volume, and particles equally well; (3) problems requiring two steps are harder than those requiring one step; (4) problems involving scientific notation are more difficult than those that do not; (5) problems involving the multiplication concept are easier than those involving the division concept; (6) problems involving the collective

word "bag" are easier to solve than those using the word "billion"; (7) use of the word "a(n)" makes the problem more difficult than using the number "1."

The purpose of a study by Gabel, Sherwood, and Enochs (93) was to determine the general problem-solving skills that students use in solving problems involving moles, stoichiometry, the gas laws, and molarity. The strategies were examined for success in problem solving for 266 students of varying proportional reasoning ability, using interviews incorporating the think-aloud technique. Data were coded using a scheme based on Polya's heuristics. Results indicated that successful students and those with high proportional reasoning ability tended to use algorithmic reasoning strategies more frequently than did nonsuccessful and low proportional reasoning students. However, the majority of all students solved the chemistry problem using only algorithmic methods, and did not understand the chemical concepts on which the problems were based.

Technology/Microcomputers

The purpose of a study by Vazquez (295) was: (a) to determine the effectiveness of computer assisted instruction on a secondary school chemistry course, and (b) to assess student attitudes toward computer assisted instruction. One group of students received chemistry instruction using the computer and a control group received instruction in the same course without the use of a computer. Data were collected to compare the effectiveness, attitude, and economy of student time of students using computer assisted instruction and those not. This research suggested that knowledge of the effects of computer assisted instruction can aid future design studies to ascertain: (a) if the reduction of instructional costs can be attained while achieving a higher performance level by students, (b) if computer assisted instruction satisfies chemistry academic needs of each individual student at his own ability level, (c) if there is any measure of instructional time using computer assisted instruction, and (d) applicability to other areas of science instruction at this level, i.e., physics, biology, genetics, and the like.

Summary

Several studies were conducted relating to learning and performance. The studies focused on instruction, instructional materials and problem solving. As in biology, the studies indicate the need for modification of instruction and instructional materials. Further research on instructional materials and instruction related to concept learning and problem solving is needed and should help to improve practice.

High School Physics

Introduction

Ten research studies related to high school physics are reported. Reports are categorized into the following sections: (1) Student Conceptions and Misconceptions; (2) Student Attitudes; (3) Teaching Methods; (4) Curriculum; and (5) Testing.

Student Conceptions and Misconceptions

Aguirre and Erickson (5) reported on a study of grade ten students' understanding, prior to formal instruction, of three vector concepts: position, displacement, and velocity. Three aspects of the study were discussed and reported. The first aspect was the conceptual analysis of the subject matter which was used to devise appropriate interview questions; the second aspect was the rule assessment methodology which was used in the compression of the interview data, and the third aspect was the substantive results obtained from interviews with the participating students. The conceptual analysis yielded ten "implicit vector characteristics around which interviews were constructed. From these interviews a number of inferred rules were developed. The rules suggest that while a majority of respondents appeared to be using rules similar to the physicists' model for a few vector characteristics, for most characteristics they used rules which are only a partial description of the phenomena from a physicist's point of view.

Ivowi (135) administered a test to Form 5 students aged 15-17 years in eight secondary schools in Nigeria to study misconceptions in physics held by Nigerian secondary school students. Findings from this study revealed that some misconceptions stem from teacher ineffectiveness, poor application, inadequate language level usage, and inadequate textbooks. Misconceptions in physics appear to be widespread and in roughly the same way amongst secondary school students in Nigeria as of those students in South Africa. Ivowi concluded that the inadequacy in human and material resources for the teaching of physics could be minimized by a more concerted effort in in-service teacher training programs, textbook production, and the better equipping of physics laboratories.

Student Attitudes

Attitudes are of interest to educators, both as influences on cognitive learning and as educational ends in themselves. When student attitudes are particularly negative toward a subject, teachers and others who are concerned with teaching the subject should examine and carefully appraise the situation. If they cannot find a way to cure the problem of negative student attitudes, they may at least find better ways to proceed in light of the problem. Bottoms (33) analyzed the attitude of high school students toward physics using three data sets: data collected for Purdue Poll 101, data collected as part of the summative evaluation of Harvard Project Physics, and data from a 1975 survey of physics students in 24 of the schools that had participated in the Harvard Project Physics evaluation. Results indicate that: (1) Physics is taken not just by the best and brightest students, but by many "average" students as well. (2) The students who dislike physics tend to be like the students who do not take physics on most measures over which the comparison can be made. (3) Physics is one of the most disliked subjects, the subject most frequently disliked by the physics students themselves.

Teaching Methods

In two reports to the National Science Foundation, Abraham and Renner (3) and Renner et.al. (233) discussed the learning cycle which consists of three phases; exploration; conceptual invention; and expansion of an idea. Inherent to the perception that students are actors rather than reactors to their environment are three assumptions: (1) each of the three phases is necessary; (2) the sequence of phases must be exploration, conceptual invention, and expansion of the idea; and (3) that the form of the exploration is students' investigation with materials. Reported are several experiments conducted to ascertain the impact of each on students' achievement of conceptual understanding and attitudes toward concepts of chemistry and physics. Concepts and principal variable (assumption) tested included: motion (form); falling bodies (sequence); mass (necessity); measuring heat in solids (necessity); some properties of an electric circuit (necessity); electricity at rest (form); and currents and magnetism (form). In addition, data related to student attitudes about laboratory work are reported and discussed.

Renner (232) conducted approximately 150 student interviews to investigate the value students attached to the laboratory activities while studying physics using the learning cycle curriculum construction and various teaching procedures. Six students were interviewed before each learning cycle began, and after each learning cycle to determine their knowledge of content, how their understandings of physics were changing, and their feelings regarding

the laboratory activities being used. Data from the interviews demonstrated that students were enthusiastic about what and how the laboratory is superior to other procedures used to supply them data.

Tessmer (284) examined the effect of a tree diagram of coordinate definitions upon a defined concept learning task. Two levels of treatment method were used: a text that arranged the definitions and examples of seven coordinated concepts in a tree-like diagram, and a text that arranged these same definitions and examples in a standard textbook format. In addition, this study examined a method of creating concept examples that required different levels of discrimination and generalization. This method was called a rational set generator. Forty-six junior and senior high school physics students were randomly assigned to one of two treatment groups. All students were given an immediate retention test and a similar measure eight days later. Analysis of test results indicated that there was a significant interaction between the text method used and the reading ability of the subjects used, with the lower ability students using the diagram method scoring higher than did the textbook subjects of the same ability.

A study by Binkley (28) analyzed relations between the content and method of instruction, and the content and method of testing to isolate factors affecting the transfer of knowledge from a textbook to students enrolled in two high school college preparatory physics classes and one career exploratory physics class. Three chapters from each class were analyzed, and achievement was measured. For the A condition, students used their standard textbooks. For the B condition, a chapter from the college preparatory text was revised, using a new text structure, and given to both groups followed by a second test. An attitude questionnaire was also administered. For the final A condition, students returned to their standard textbooks for the next chapter and took the third teacher-made test. When the new text structure was employed: (1) College preparatory and career exploratory student achievement increased significantly in questions whose answers involved application and/or discussion. (2) Speed of reading was not facilitated. (3) Across all the chapters, college preparatory students maintained a low or middle C level of achievement while career exploratory students achieved a middle D level of achievement.

Curriculum

Pfeiffenberger and Wheeler (218) report the results of a national survey of high school physics courses. The survey consisted of a questionnaire mailed to every 7Sth high school on a list of nearly 2400 schools in the country, making a total of 317 schools surveyed. Private schools were represented as were schools from rural, suburban, and urban areas. Questions asked in the questionnaire included: the time devoted to teaching major physics content areas; subtopics in

each area; equipment students saw and used; principal textbook used; and school/physics enrollments. While the data obtained cannot be used to establish definite rules, they do provide some guidelines in developing the Physics Achievement Test.

Testing

Verkerk (296) conducted a research project aimed at giving Dutch physics teachers clearer ideas on the assessment of practical work and to show what abilities can be tested by practical examinations. Collaborating with teachers at seven secondary schools, Verkerk gave several kinds of practical examinations to physics students during a four year period. The study showed that some abilities can only or best be measured by means of practical testing. Results suggest that a practical test be composed of two parts: performing an experiment, and interpreting and analyzing an experiment.

Summary

While there were relatively few studies related to physics, several focused on learning and instruction. These studies indicate, as has past research, that different instructional procedures and different instructional materials usually result in different learning. As in biology and chemistry, suggestions for improving practice are available.

University Geology

Introduction

Four studies were reviewed which were related to university level geology. No attempt was made to group these studies into subcategories.

Research Studies

Kern and Carpenter (142) compared the effectiveness of teaching earth science in the traditional manner to that of a field-oriented approach. To measure the effect of field activities on the affective responses of students, very different approaches were used by the same instructor in teaching two sections of earth science laboratory. One section was conducted in the traditional manner. It involved primarily classroom activities using a lab manual. A field-oriented, on-site approach was employed for the second section. The content was virtually identical in the two sections. Both classes were pretested

for values (sense of importance), attitudes (sense of enjoyment), and interests as related to the 30 major topics of the course. Topic tests indicated that there were no significant differences between the two classes. At the end of the term, post-tests revealed that students who experienced the field-oriented approach left the course feeling much higher levels of importance, interest, and enjoyment associated with the learning experience than did students in the traditional lab.

Mims (190) sought to identify which selected instructor and institutional characteristics significantly affected the utilization of instructional media and techniques in college physical geology courses. A secondary purpose of the study was to determine the frequency of utilization of each instructional medium and technique among the geology instructors in order to form a basis for comparison of their instructional methods. Questionnaires were sent to 60 geology instructors in the state of Texas and 71 instructors in 34 other states. Significant differences were found among the frequencies of utilization of instructional media and techniques and ten of the instructor and institutional characteristics. The most frequently utilized instructional media and techniques were: chalkboards, textbooks, lecture, discussion or questioning, and textbook reading assignments.

Westerback, Gonzalez, and Primavera (306) compared anxiety levels of students in introductory earth science and geology courses. Students in each course were split into two grade groups. It was shown that students whose grades were higher had low anxiety, which continued to be reduced during the course. Students in the lower grade group had high anxiety, which increased during the course. There was no difference between anxiety scores of males and females. In general, students who planned to elect additional courses had lower state anxiety and higher grades than students who did not plan to elect additional courses in geology and earth science.

A study reported by Kermis (141) had three purposes: (1) to report "potent" testing cues (i.e., 90 percent response agreement for both intensity and frequency) that were identified by high-test-anxious (HTA) and low-test-anxious (LTA) students; (2) to report differences between HTA and LTA students for frequencies and intensities of responses to testing cues; and (3) to report differences between HTA and LTA students of attentional direction to testing cues. A pool of 396 males and females enrolled in physical geology completed the State-Trait Anxiety Inventory. A random sample of 93 HTA and 40 LTA subjects completed the Test Cues Identification Questionnaire (TCIQ). The TCIQ consists of 28 disruptive items and 27 helpful items. Subjects responded with both frequency and intensity ratings for all 55 items in the TCIQ. Results revealed that 22 items were viewed by subjects as "potent" testing cues. Evidence did not support previous theoretical reports of differences between HTA and LTA students for either frequency and intensity of anxious responses or attentional direction to the set of disruptive and helpful testing

cues. Although test anxiousness did not appear to be associated with those two characterstic differences, a discriminant analysis revealed 24 items in the TCIQ which significantly separated HTA and LTA subjects' responses. Apparently, HTA and LTA students differ in their responses to the set of testing cues as was previously postulated.

Summary

With so few studies in this category, no attempt can be made to generalize from the findings reported. It is suggested that reviews from earlier years be consulted in developing a more comprehensive view of the status of research in geology education at the college level.

University Biology

Introduction

Twenty-two studies are reviewed in this section, grouped into seven subcategories: (1) Student Characteristics; (2) Student Conceptions and Misconceptions; (3) Teaching Methods; (4) Curriculum; (5) Textbooks; (6) Problem Solving; and (7) Technology. With the exception of teaching methods and technology, most of the subcategories contain one or two studies, indicating something of the diversity of interest in the research in this general area.

Student Characteristics

In order to examine the possible relationship between visual-spatial aptitude and the study of college biology, Lord (173) conducted a study on 125 undergraduates majoring in the biological sciences. One hundred twenty liberal arts majors were also tested in the study to note any similarity or difference in the two populations. All subjects were given pretests to judge their spatial potentials. The biology population was divided into three groups (control, placebo, and experimental), each consisting of roughly 20 males and 20 females. Throughout the year, subjects in the experimental group were given laboratory exercises aimed at developing their spatial perceptive capabilities. The placebo group was given a thirty-minute presentation each week on the historical development of the laboratory topic, while the control group received exercises from a marketed general biology manual that involved little visuo-spatial understanding. The pretests indicated that students who had selected biology as their field of specialization scored much higher on the spatial tests than did the nonscience majors. Interestingly, the

females in the population who had selected biology as their major scored significantly higher on the tests than either the males or females who selected nonscience disciplines. This result seems contradictory to the notion that males are more spatially gifted than females. The research indicates also that a student's spatial ability can be significantly increased through interaction. Students in the experimental populations showed significant improvements in spatial posttest scores when compared to the placebo, control, and nonscience populations. This study, therefore, supports the idea that spatial thinking can be strengthened and improved through practice.

Cortina (59) attempted to determine the reading skills that community college faculty perceive as necessary for students' success in certain English, history, and biology courses. Sixty-one faculty from 19 Texas community colleges completed three questionnaires. All three disciplines rated three reading skills to be essential to their students' success: locating or determining main ideas, following printed directions, and using study time efficiently. Another 16 skills were rated to be of high importance by all three disciplines including summarizing key ideas, identifying supporting details, organizing ideas by classifying, reading for a specific purpose, and formulating generalizations.

Student Conceptions and Misconceptions

Brumby (37) conducted a study of 150 first year Australian medical students from one university in order to further explore the conceptual frameworks and reasoning patterns related to natural selection. Several unfamiliar qualitative problems based on the concept of natural selection were designed and given to the students in three different formats: a set of written problems; individual structured interviews; and one natural selection question on the end-of-year examination. Results clearly demonstrate that the majority of these science students leave school believing that evolutionary change occurs as a result of need. Brumby suggests that a reason for this misconception is the way science is presented in lectures. Science to the students is seen as a body of absolute knowledge, to passively memorize the content of their lectures, and learning "what" not "how." There are several implications from these results for improving student learning. One is that lectures, which are a form of passive learning, are insufficient in themselves to create conflict in students' minds to alter their existing understanding.

Teaching Methods

There were two purposes addressed in a study by Helseth (119). The first was to assess the effectiveness of an instructional strategy

in promoting biology achievement and formal operational thinking ability (FOTA) of preservice elementary teachers enrolled in a college biology course. Two contrasting instructional strategies were used. One strategy provided students practice in using the integrated science process skills and opporunities to solve problems related to the biology content. The contrasting strategy employed an expository lecture method and lacked the process skills emphasis or problem solving experiences. The second purpose was to determine the relationships among students' entry characteristics, biology achievement, and FOTA after a quarter of instruction. The entry charactersitics were: locus of control, academic aptitude, integrated science process skills ability (ISPSA), achievement motivation, and FOTA at the beginning of the study. Treatments were randomly assigned to intact classes. The instructional strategy emphasizing integrated science process skills was not effective in promoting significantly higher biology achievement and FOTA. Students' ISPSA, mathematics aptitude, and FOTA were consistently related to biology achievement or FOTA at the end of the course. Students' locus of control and achievement motivation were not related to biology achievement or FOTA at the end of the course. The effects of pretesting students' ISPSA and FOTA were difficult to assess in some cases, due to nonequivalent pretesting groups. There was clear evidence that some portion of the increase in students' FOTA was related to the effects of pretesting.

Leonard (165) tested a laboratory teaching approach known as the extended discretion approach (ED) in a university setting. The ED approach gives the students a task, from two to five brief procedural steps, and a list of resources from which to choose. The students must exercise discretion in the use of available resources to complete the task. General biology students using this approach were compared to students receiving conventional instruction. Results showed significant differences between groups only for the laboratory reports and these favored the conventional approach. Since students performed at least as well using the ED approach which is more demanding and challenging than using another method, there is still reason to consider further the ED approach.

Walkosz and Yeany (299) compared the process skill achievement of students (n=107) completing traditional laboratory exercises with students (n=127) not only completing the same exercises but also receiving instruction in such integrated process skills as identifying variables and stating hypotheses. The relationships among process skill achievement, cognitive development, overall course achievement, sex, and attitudes were also examined. Results indicated that emphasis on process skills in the laboratory can significantly improve process skill achievement. Students with lower levels of cognitive development had a lower level of process skill achievement across levels of cognitive development. Females on the average had a slightly lower level of cognitive development than had males, but there was no sex difference in process skill achievement overall. However, statistical interactions indicated that females at the lowest level of cognitive development scored higher on some of the process

skill measures than did males at the same level of cognitive development.

Firstman (87) used a quasi-experimental design in an investigation directed at determining whether laboratory time in microbiology would be more efficiently and effectively utilized if scheduled as semi-weekly sessions of one-and-a-half hours each rather than as a single three-hour session. Efficiency was measured by the number of procedural and data errors made by students and the amount of time actually spent in lab. Learning outcomes, scores on an epidemic problem-solving assignment, and mean laboratory examination scores were used to denote effectiveness. Subjects consisted of two intact laboratory groups with 24 students in each group. Significant differences were noted between the two groups. Students in the semi-weekly section spent more time in the laboratory, made fewer procedural errors, fewer data errors, and had higher mean laboratory examination scores. However, no significant differences were noted for the epidemic problem set. It was recommended that serious consideration be given to offering additional microbiology laboratory sections on a semi-weekly basis as a method for improving management of the learning environment.

With respect to the discovery of a specific methodology to promote science literacy, the purpose of a study by Templin (283) was to compare the effects of two methods. Each was implemented in a college freshman biology class for nonmajors, Human Heredity and Development, taught at the University of Delaware. One method was the PQRST (P=preview, Q=question, R=read, S=summarize, and T=test). In part, the goal for this study was to seek a viable alternative to the PQRST that could better ally reading science instruction. Such an alternative is meaningful, based on the idea that reading instruction can join science content with the reading and reasoning process by which the content is learned (read to learn). Although little empirical evidence exists for this approach, a potential liaison is offered by the functional teaching (FT) method. It was used in this study as the second treatment. Results of this comparison showed both treatments to be effective in producing achievement at the application level, as defined by Bloom, with no significant differences, however, between the two. The FT method also positively changed students' attitudes to achieve.

A study by Anderson (14) attempted to implement intervention designed to instill affective professional attitudes in the clinical laboratory scientist. Twenty-one clinical laboratory science students were included in the study. The students were blocked with respect to experience and intellectual ability and then randomly assigned to either the treatment group or the control group. The treatment group received instruction designed to instill a professional attitude through the use of written simulations. It was anticipated that the frequency of errors occurring during the performance of laboratory determinations would decrease as a result of the intervention when compared to a base line error rate established by the control group.

However, no difference existed between the treatment and control groups.

The purpose of an investigation by Burnett (34) was to study the effects of a laboratory versus a no-laboratory sequence on student achievement in the cognitive domain of the lecture section in Agricultural Biochemistry 210 at the University of Missouri-Columbia. Subjects (n=151) were randomly assigned into three laboratory sections and into two treatment groups per laboratory section. Experimental subjects were treated by a group taking lecture with laboratory and a group having lecture only. During the second phase of treatment, subjects received the opposite treatment. Achievement scores were not significantly different among the sections, thus, it was concluded that the present laboratory sections did not contribute significantly to achievement in the lecture.

Riggs (236) evaluated the effects on student achievement of a laboratory manual utilized in the Introductory Animal Science classes at Colorado State University. Student achievement in a control semester without the use of the lab manual was compared with student achievement in two semesters in which the laboratory manual was used. It was found that the laboratory manual had a positive effect on student achievement. Specifically, there was a greater chance of students getting a B instead of a C and a lesser chance of getting a D or an F.

Curriculum

Two different study sites (University of Maryland at College Park and State University College at Buffalo) were examined by Kinsey and Wheatley (143) to see if the completion of an environmental studies course affected the defensibility of environmental attitudes. The general trend was toward a more defensible attitude (one with more informational supports). These observations support a hypothetical connection between the cognitive and affective domain and suggest that, after being exposed to environment content, student attitudes should be examined for stronger attitudinal supports rather than for large changes in attitudes.

Textbooks

Laing (150) investigated various anatomical concepts in existing anatomical texts which may have been incompletely, confusingly, inaccurately, or never illustrated, and designed graphics which would visualize more adequately the verbal descriptions for greater reader understanding. The concepts illustrated were: (1) the distal structure of the humerus, (2) the mediastinum, (3) selected peritoneal derivatives, and (4) the relationships of the structures of the pelvic diaphragm to urogenital diaphragm.

Leonard and Lowery (166) investigated the effects of textbook question type upon retention of biology concepts in a sample of 383 university general biology students. Contrary to previous studies, they found that retention was not enhanced by any of the four question types used (hypothesizing, factual, valuing, rhetorical). Further, the questions actually resulted in less learning (or more forgetting) particularly over the mid to long-range time intervals.

Problem Solving

Smith and Good (256) extended expert-novice problem-solving research to include classical genetics. Eleven undergraduates (novices) and nine graduate students and instructors (experts) were videotaped as they solved moderately complex genetics problems. Detailed analysis of these "think aloud" protocols resulted in 32 common tendencies that could be used to differentiate between successful and unsuccessful problem solvers. Experts perceived a problem as a task requiring analysis and reasoning and they tended to use a knowledge-development (forward-working) approach. They made frequent checks on the correctness of their work, used accurate and detailed bookkeeping procedures, and had a broader range of heuristics to apply to the problem. It is clear that studying problem solving using the expert/novice design requires that the problems be difficult enough to require more than more recall and yet simple enough to allow novices a chance for solution. Applying elementary probability concepts seemed to be the most difficult aspect of many of the genetics problems, even for the experts.

Costello (60) undertook a study to analyze the errors made by students solving genetic problems. A sample of 10 non-science undergraduate students was obtained from a private college in Northern New Jersey. The results supported prior research in the area of genetics education and showed that a weak understanding of the relationship of meiosis to monohybrid and dihybrid cross problems interfered with the ability to develop meaningful solutions. Furthermore, successful algebraic manipulations did not ensure an understanding of gamete genotypes, and random segregation of chromosomes was often not understood.

Technology

Audio-tutorial

Collier (55) investigated the improvement of achievement in an audio-tutorial botany program using one variable, student-generated analogies. The purpose of this study was to determine if

undergraduate students could increase their level of achievement by incorporating analogies into the instructional setting. Their performance in the course was then evaluated and compared to other members of the course. University botany students (n=530) were randomly assigned to three groups. One group was required to produce three analogies per week in relation to their weekly botany information; the second group interacted with the same instructors as the first group but were not required to make analogies; and a third group, not required to make analogies, interacted with different instructors. Although most results yielded higher means for the analogy group, the results were statistically not significant.

Rivero (237) compared two instructional methods, audio-tutorial (AT) and conventional expositive, in teaching natural science at the college level. The two groups of 21 students were randomly selected from a population of 102 students and tested over a period of six weeks. Measurements of immediate achievement and retention were obtained during the first week of study (pretest) and during the sixth week (posttest). Three weeks after the students were posttested, a follow-up test (retest) was administered. The A-T instructional group scored significantly higher in the immediate achievement and in their level of retention and remembered about 10 percent of the mastery knowledge tested by the retest. The A-T group did not achieve as high a level on "memory" items. However, the A-T group retained about 50 percent more knowledge (memorization) than did the conventional group. The A-T method resulted in higher achievement on "analysis" items and retained 80 percent of the posttest mastery knowledge, whereas the conventional group retained their same mean scores.

Microcomputers

Self, et. al. (247) attempted to facilitate the learning of biology by students with poor reading skills through the integration of computer assisted instruction with a classical audio-tutorial biology course. Two trials of the study were conducted. The study consisted of 20 students in the control group and 20 students in the experimental group. The experimental group was exposed to a computer program that was designed to provide immediate feedback on the student's achievement. Other than this, both groups were exposed to the same learning experiences. Reading scores for all students were obtained. Results from testing suggest that the performance in a biology course of poor readers can be improved when they are provided with updated advisement information about their achievement and instructional needs.

Peard (214) examined the understanding of Mendelian genetics of students in introductory college biology. Of primary concern was the role of the microcomputer in identifying student conceptual frameworks and its potential for contributing to meaningful learning. Students' pre-instructional knowledge was assessed using a multiple-choice test

followed by an interview. The biology course was taught in an auto-tutorial format. Twenty volunteers worked genetics problems via a microcomputer laboratory simulation program. Another 20 students continued to work similar text problems in the conventional paper and pencil manner. A wide variety of conceptual weaknesses, missing concepts, and misconceptions were identified. The concept maps, interview transcripts, written tests, and problem-solving strategies showed agreement in the identity of several conceptual difficulties. Several such difficulties were observed to negatively influence problem solving. Some persisted through to the end of the course. The microcomputer laboratory program used--CATLAB--was determined to be an exceptional means of assessing conceptual frameworks and identifying problem-solving strategies.

An evaluation study comparing a computer assisted learning-based project with three more conventional ones in an Open University course on evolution was reported by Hodgson and Murphy (123). Special attention was paid to reasons why students chose to do different projects and the factors contributing to the variance in the marks awarded for their work.

To investigate whether learning improved with computerized tests Collins (56) conducted an experiment using 210 students that had registered for a one-semester, non-credit introductory university biology course. There were six different sections in the course and one class, designated "Computer Section," was to use the computerized tests previously developed by the author. To evaluate whether there was improved learning with computerized tests, an analysis on the following was done: (1) differences in performance on written class tests between users and non-users of computer tests, (2) differences in mean test scores of computer and non-computer classes, (3) student questionnaire, and (4) instructor opinion. The experiment results indicated that computer administered tests did lead to enhanced learning in biology as measured in terms of test scores. Collins suggests that computerized tests can also be used as pretests for students to determine which parts of a topic they know or don't know in advance of learning the topic. Computerized tests also enable instructors to reduce their normal marking load and use their time more effectively.

Summary

With the variety of studies and variation in findings, drawing any generalizations would be risky indeed. Three factors, not newly identified in this review, persist: the effectiveness of one or more methods or approaches to instruction, the relationship of the laboratory to achievement in science and to attitudes toward science, and the relationship of science processes to cognitive gains. Rather than developing conclusions on the basis of the research reported in a single year about any of these factors, a more sound approach would be

to refer to the recent meta-analyses that have been reported and to consider the findings reported over the past years in other reviews of research.

University Chemistry

Introduction

The eleven studies reviewed in this section have been grouped into five categories: (1) Teaching Methods; (2) Curriculum; (3) Textbooks; (4) Problem Solving; and (5) Technology/Microcomputers. The first two areas have four studies each, the remainer one or two, indicating the relative areas of interest in research in chemistry education at the college level this past year.

Teaching Methods

Isom (134) studied the effect of the prelaboratory preparation period on students taking introductory chemistry at Auburn University and described the nature of the prelaboratory preparation period as an alternative teaching technique for the laboratory setting. The General Chemistry Laboratory Program consisted of seven weekly laboratory exercises. During the four quarters of 1979 when the study was conducted, a sample of 301 students comprising ten separate groups drawn from a total population of approximately 1,800 students was divided into six experimental and four control groups. The posttest-only control group design was utilized to investigate the nature of the prelaboratory preparation period and its effect on academic performance. While not statistically significant, experimental groups scored higher on all laboratory exercises with the exception of L7, "Stoichiometry of the Lead II Potassium Halide Water System." A significant difference existed on overall laboratory performance.

The majority of investigators use performance on a final examination to test the effect of PSI (personalized system of instruction) versus traditional teaching. Freeman (90) used the success of its graduates on the same topic in more advanced courses as a means to compare the PSI students with those in a traditional remedial chemistry course. The two courses were compared on the basis of attrition as well. Students who were regularly registered for the two courses that operated side-by-side were used for this study. Neither course was identified as experimental. Three separate but similar studies were designed to test for differences in performance after the remedial experience. Although the PSI course suffered heavy attrition, PSI students did significantly better in later courses in chemistry and their advantage held up over time.

Ertwine (82) reported on the evaluation of two teaching methods at the United States Military Academy. The Thayer Method, which is used at the United States Military Academy, is offered as an alternative teaching methodology which has many of the desirable PSI characteristics. Under the Thayer Method, students are provided with all course materials and performance objectives. They prepare lessons prior to class and write periodic quizzes and exams. The classes are instructor-paced with a low student/instructor ratio to enhance discussion. Two sections of 20 students each were taught a second semester general chemistry course by the Thayer Method and two other sections were taught by the traditional lecture method. The objective of the study was to validate or invalidate the Thayer Method as an alternative to PSI. An analysis of student achievement showed no statistically significant performance differential between the Thayer and lecture methods. The results of an attitude survey indicated that both groups of students preferred the method by which they were taught, although the students in the lecture sections indicated a slightly more positive attitude toward the course. The conclusion reached is that the Thayer Method is a viable alternative for institutions which choose to abandon the traditional chemistry lecture format in search of the advantages offered by PSI-type instruction.

Al-Ruwashid (12) compared effects of two approaches of teaching a complementary chemistry course upon students' achievement, attitudes toward science, and scientific attitudes. The sample consisted of 128 students registered in Chemistry 041 at Riyadh Junior College (Saudi Arabia) during the Fall Semester of 1983. The students were randomly assigned to six sections. Three sections consisting of 62 students were taught by the lecture-only approach and three sections consisting of 66 students were taught by the lecture-laboratory approach in which a guided-inquiry laboratory was adopted. Conclusions included: (1) the lecture-laboratory approach was significantly more effective than the lecture-only approach in enhancing students' chemistry achievement; and (2) the lecture-laboratory approach was significantly superior to the lecture-only approach in fostering students' scientific attitudes (intellectual attitudes), attitudes toward science (emotional attitudes), and total science attitudes (intellectual and emotional attitudes).

Curriculum

The purpose of a study by Plumlee (219) was to determine an optimum content hierarchy for one topic in a college chemistry course. The study involved the development and validation of the hierarchy leading to the terminal objective for the unit on equilibrium, Le Chatelier's Principle. Terminal objectives were identified for related problem solving areas. Prerequisite objectives were identified. Each prerequisite skill was further analyzed until entry level skills for the instructional unit were determined. Two questions were written for each of the objectives and were grouped

into three related exams. Pairs of objectives were confirmed through the analysis of the test results using the method developed and reported by White and Clark. A matrix of student performance was prepared, cross referencing performance on each test item for the terminal skill in the cell and its relationship to performance on the prerequisite skill. From these data the probability of a student having the higher level skill and not having the hypothesized lower skill was calculated.

Pestel (217) evaluated the freshman chemistry program at Lehigh University. The components of the program evaluated were: course content, course design and presentation, the role of the graduate teaching assistant, laboratory design, learning centers and computer-aided instruction, and course management. Each component was developed and integrated into the whole in a manner that was consistent with Piagetian learning theory, the needs and interests of the students, and the facilities and mission of the university.

Mulder and Verdonk (199) used observations of a student and a teaching assistant to redesign a teaching unit on recrystallization to use in a freshman chemistry course. The student who was to be the object of observation was supplied with a VHF transmitter microphone. This made it possible for conversations between the student, his lab partner, and the laboratory assistant to be received and tape recorded. An observer listened (using an earphone) so that he received visual and auditory signal simultaneously. These were noted and supplemented the more formal report on the observation. With data obtained from the observations, starting points for a teaching unit on recrystallization were derived. Some points made were that the teaching unit should be more than a handbook; it should make the student more aware of the nature of his problem; the assistant must be actively involved in the teaching unit; and it should not prescribe in detail the method to be followed. Also obtained from the data were a list of objectives and tasks for the teaching unit.

To determine the course content and priorities in the teaching of biochemistry to nutrition/dietetics students, Sirota (252) mailed two questionnaires to the Director of Dietetics at all 251 institutions offering dietetic programs. Directors were requested to forward the questionnaires to the instructors of the appropriate biochemistry courses. Responses indicated that there was great variation in the biochemistry education of dietitians and that this variation was influenced by whether students in other major fields were also in the biochemistry course.

Textbooks

Falkowski (83) reported the results of a study of the relationship between readability of a chemistry textbook and performance in first year college chemistry. Subjects were 52 college

chemistry students. Nonsignificant correlations were found between scores on a standardized reading test and the final chemistry grade, between scores on special chemistry reading tests and final chemistry grade, between standardized reading test scores and the test scores of the special chemistry reading tests, and between scores on the special and technical vocabulary test and scores on the special chemistry reading tests. A significant positive correlation was found between chemistry reading test scores of students provided with vocabulary lists and definitions and those students not so provided.

Problem Solving

According to Greenbowe (103) success in solving science and mathematics problems evidently depends upon variables such as content knowledge, level of intellectual development, the use of heuristics, the ability to construct an appropriate problem representation, and the number of errors committed that remain uncorrected. Greenbowe's study was an effort to learn more about the effect of these and other variables on success in solving chemistry problems. Subjects were 30 college chemistry students and one college chemistry professor. Most of the subjects demonstrated proficiency in basic algebra, chemistry, and cognitive skills. The subjects individually solved chemical stoichiometry problems using the think-aloud technique. Each session was audio-recorded for subsequent analysis of problem solving techniques and chemistry content exhibited by the subject. The major findings were: (1) Problems involving simultaneous reactions proved to be difficult regardless of chemistry background. (2) Successful problem solvers were able to construct and use an appropriate representation for the problems. Unsuccessful problem solvers focused on an inappropriate balanced equation and used an algorithm (the factor-label method). (3) Problem representation was found to influence the manner in which individuals apply concepts. Conceptual understanding was found to influence an individual's problem representation. (4) Successful problem solvers appeared to use three levels or modes of representation (symbol, microscopic, and macroscopic) in order to understand the problem. (5) Successful problem solvers exhibited more effective problem solving skills (organization, persistence, evaluation, heuristics, and formal operations) than did unsuccessful problem solvers. (6) Both content and process variables are important for successful chemistry problem solving. It is not known whether individuals are able to acquire chemistry concepts because they are proficient with process variables, or whether individuals are able to apply process variables because they understand chemistry concepts.

Technology/Microcomputers

Zitzewitz (329) conducted a study of learning from microcomputer programs in college general chemistry. The learning and achievement accomplished by 54 general chemistry students who used four microcomputer drill and practice programs was compared with that of 41 students who did not. No significant difference was observed in performance although small gains by program users were found. The majority of the students in the study indicated that they found the programs to be helpful and wanted to use similar programs to learn other subjects.

Russell (242) investigated the interactions of four student aptitudes (vocabulary skills, spatial relations abilities, field dependence/independence and prior chemistry knowledge) with the use of videotaped and computer-based instructional materials already in place in the freshman chemistry curriculum at UCLA. Data analysis showed significant differences on the aptitude variables between males and females. In each case the difference was in the direction reported in the literature based on less selective samples. Several interactions were found: weaker students used the videotapes more frequently than did the more able students; females used them more than did males; field-dependent females had the greatest degree of difficulty in using the computer; the weaker the students were academically, the more difficulty they had using the computer.

Summary

With the relatively low number of studies in any one category, no attempt can reasonably be made to draw generalizations. It appears, as other reviews have indicated, that individualized approaches and multiple technique approaches to teaching chemistry may well be more successful than either group or single technique approaches. Again, consideration of the research over a longer period of time is needed to develop more useful conclusions.

University Physics

Introduction

The concentration of research in college science education reflects the pattern observed for high school science with biology drawing the most attention, followed by chemistry, then physics, and finally, the earth sciences. The ten studies reviewed in this section are categorized as: (1) Student Characteristics; (2) Student Conceptions and Misconceptions; (3) Teaching Methods; (4) Problem Solving; and (5) Technology/Microcomputers.

Student Characteristics

Wollman and Lawrenz (316) attempted to identify potential "dropouts" from college physics classes. Previous research has established that mathematics ability is probably a secondary factor influencing dropout from college physics courses. When mathematics ability was coupled with general indicators of performance (total GPA and ACT, natural science), prediction of performance of those who complete the course was substantially improved. Moreover, discriminant analyses revealed who will have at least some difficulty, but not who will drop out. The problem of isolating specific weaknesses of students who have difficulty persists. Physics achievement appears to depend on mathematics ability only to the extent that students possess the ability to utilize mathematics knowledge for solving physics problems. Identification of the specific aspects of this ability as well as the specific deficiencies leading to dropout should be the object of future research.

Pallrand and Seeber (211) reported research undertaken to clarify the nature of the relationship between visual-spatial abilities and achievement in science courses. A related purpose was to determine what influence visual-spatial abilities have on the high attribution rate characteristic of many introductory college-level science courses. Three sections of introductory college level physics (n=136) and one nonscience liberal arts section (n=52) received pre- and postmeasures of visual-spatial ability in the areas of perception, orientation, and visualization. Increases in visual-spatial abilities were greatest with an experimental section that received a spatial intervention. These gains were related to test items that utilized graphical form and to laboratory work. Substantial gains in visual-spatial ability were also registered by a placebo and by control sections. These increases suggest that taking introductory physics improves visual-spatial abilities. Although students who withdrew from the course demonstrated mathematics skills comparable to those of students who completed the course, their scores on perception tests were appreciably lower. Visual-spatial scores of the liberal arts group were lower than those of the physics sections, suggesting that visual-spatial ability influences course selection.

A study by Spickler (268) asked: Can physical intuition (insight) be strengthened within a physical science laboratory? Will intuition enhance science achievement and information process skill? A model of intuition was designed using the framework of Polanyi's tacit theory of knowledge and the Neo-Piagetian paradigm. Fifty-nine elementary education majors were divided into treatment and control laboratory sections. Treatment consisted of concrete, manipulative exercises with key experiences in measurement, pressure, Archimedes' principle, machines, and electricity. Pretests, summative tests, and posttests were examined using the analysis of covariance and a variety of t-tests in order to deduce the results of the study. (1) Intuition was significantly stronger among the treatment sections according to a

posttest covering skills explicitly developed by the treatment exercises. (2) Science achievement was only enhanced for the treatment group on the scheme for pressure. (3) Likert attitude scales on instructor effectiveness, laboratory effectiveness, and science attitude were significantly higher for the treatment group. The course difficulty scale revealed no significant difference. (4) ANCOVA showed a significant treatment superiority at the comprehension level while knowledge and application level differences were insignificant. (5) Digit span and spatial visualization were used in a regression equation to predict scheme achievement. The coefficient for digit span showed a significantly higher loading for the treatment group suggesting that intuition activates encoding of information into short term memory.

Student Conceptions and Misconceptions

Lawson (159) reported the findings of an investigation of student understanding of the concept of force, the connection between force and motion, and the work-energy and impulse-momentum relations. The operational criterion for understanding used in this investigation was the ability of a student to apply a concept to the analysis of a simple observed motion. About one hundred physics students enrolled at the University of Washington participated in the study. During interviews, students observed, described, and analyzed motions of one or more frictionless pucks that moved on a smooth level surface. The students were asked to modify the motion of the pucks through the use of a device which applied a force that could be varied in both magnitude and direction. Data suggest that students have difficulty applying their knowledge of physics to the analysis of simple observed motions. Students revealed a variety of conceptions of force and a number of beliefs about the connection between force and motion that are at variance with the Law of Inertia and the Second Law of Motion. Students who had recently studied the work-energy and impulse-momentum relations had considerable difficulty applying these relations to the analysis of a simple observed motion.

Poduska (220) evaluated the performance of college students on Piagetian-type tasks related to speed. One hundred freshmen and sophomores were individually shown demonstrations of equipment for each of the six tasks. A set of open-ended questions based on the demonstrations was administered. The concepts tested were: (I) conservation of distance; (II) asymmetric series of speeds; (III) one-to-many speeds; (IV) symmetric speeds; (V) time; and (VI) proportional reasoning. A scalogram analysis of the data indicated that the tasks formed an unidimensional scale. The tasks were found to be increasingly difficult in this order: I through VI. Results of the study have implications for teaching introductory college physics courses. The traditional method of presenting speed as a ratio of distance/time may not be appropriate, since only 8 percent of the subjects demonstrated proportional reasoning in the shadows task, and

only 18 percent demonstrated fully developed mental structures for time. The study showed that more students (20 percent for symmetric speeds, 41 percent for circular speeds, and 48 percent for asymmetric speeds) have mental structures for dealing with speed directly rather than with formal proportional reasoning.

Teaching Methods

Srivastava (270) conducted research to answer the following questions: (1) Does instruction in mathematical modeling improve students' modeling skills? (2) Does instruction in mathematical modeling lead to savings transfer in learning physics? (3) Does a mastery learning strategy lead to greater savings transfer than a non-mastery strategy? Students enrolled in three classes of a beginning physics course were selected for the study. All were pretested on their knowledge of mathematics, reasoning skills, and modeling skills. During the first instructional period, one class was taught mathematical modeling using a mastery learning approach. Another class was taught mathematical modeling using a non-mastery approach. The third class was shown physics-related films during this period. At the end of the first instructional period, all subjects were given a posttest of modeling skills and a pretest on their knowledge of physics. During the second instructional period, all subjects were taught a physics unit on momentum and energy using a mastery approach. At the end of this period, all subjects were given a physics mastery test and a retention of modeling skills test. Findings of the study were: (1) Instruction in modeling resulted in acquisition and retention of modeling skills. (2) Instruction in modeling using a mastery strategy resulted in greater acquisition and retention than instruction in modeling using a non-mastery approach. (3) Instruction in modeling leads to savings in time taken to master a physics unit. (4) Instruction in modeling resulted in shortening of the time required to master each objective (rate of mastery) in the physics unit. (5) Instruction in modeling led to a positive index of savings transfer.

Problem Solving

Wright (319) evaluated the program of Explicitly Structured Physics Instruction (ESPI) which was developed to teach problem solving skills explicitly at Virginia Polytechnic Institute. The program is designed to help students organize their work, increase their accuracy, eliminate initial panic or lack of direction in approaching a problem, increase confidence in problem solving, promote understanding instead of rote memory, and improve the students' ability to communicate with the instructor and other students. It provides not only an explicit strategy for problem solving, but also a structure for examining formulas called the formula fact sheet, and an

opportunity for practice and feedback in a problem solving session which involves the use of thinking out loud. The program of ESPI was developed over five academic quarters of testing. Reaction to the program in its final revised form was very positive. Over 90 percent said that they would use the strategy even if it were not required, and that the formula fact sheet had been very helpful. Final grades of those who used the strategy were significantly higher than those who did not. Retention of students in the course was raised from 70 percent to 86 percent.

Heller and Hungate (118) discussed research on the processes by which individuals progress toward expertise in scientific domains. Focus was placed on the activity of constructing qualitative problem representations during solution of standard mechanics problems in physics. They include information on: (1) descriptive analyses of problem-solving performance; (2) prescriptive models of problem-solving performance (which specify the knowledge required for novices to perform well on particular tasks); (3) a prescriptive theory of problem description (which specifies a procedure leading to construction of correct mechanics problem descriptions); (4) a theory of instruction which incorporates a particular model of learning-centered coaching referred to as "Evolving External Control Knowledge" (EECK); (5) the development of computer-oriented instructional materials based on the prescriptive theory and the EECK; and (6) preliminary results, focusing on possible relationships between changes in subjects' (n=9) performance and features of both the model of performance and the model of instruction. Results (among others) indicate that subjects seemed to be internalizing the notion of force as a kind of interaction and that the instructional materials are differentially appropriate for individuals at different stages of learning.

Champagne, et. al. (47) described research which led to an instructional design approach which is an alternative to consideration of such issues as mathematical skills or level of cognitive development. The approach uses an analysis of traditional instructional tasks to specify the underlying cognitive processes and structures necessary for the successful completion of the tasks; that is, a cognitive analysis of instructional tasks, rather than a logical analysis, is used to arrive at appropriate instructional goals. The approach involved taking a standard form of a question and converting it to a qualitative problem. Appropriate levels of existing relevant knowledge and experience are then determined, and a series of questions and specific, single-observation laboratory exercises are used to gradually develop a schema for the problem solution. The interaction implicit in the strategy allows for the retention of appropriate aspects of existing schemata and the modification of conflicting aspects. Two broad aspects of differences between physics experts and novice physics students relevant to physics problem solving are considered in the approach.

Technology/Microcomputers

Steidley (274) investigated the perceptions of college and university physics professors concerning the amount and kinds of instruction about the computer that should occur in the undergraduate general physics sequence. According to professors, a computer literate graduate of the general physics sequence should have developed fundamental skills of programming in the BASIC language, should be able to translate the traditional mathematics tools of physics to the computer to save time, should be able to use the computer for laboratory data acquisition and analysis, and should be able to use computer simulations in the laboratory.

Summary

Because of the small number of studies, no generalizations will be indicated. It should be noted, however, that some of the findings are consistent with research in other areas and from other reviews. While mathematics is related to achievement in physics, it is clearly not the only factor; evidence reported in the studies in this section indicate that such things as visual-spatial abilities, intuition, and problem solving ability may also be related. The data from several areas suggests strongly that students frequently hold concepts that are at variance with those accepted by the scientific community; college students in physics do not appear to be exceptions to this. It has also been reported in other studies that instruction frequently is not appropriate for the development level of the students; again this appears to hold true at the college level. Finally, there is evidence to suggest that some structure, such as a problem solving strategy or a modeling approach, may be effective in improving learning in physics as well as in other disciplines.

Informal Science Education

Introduction

Five studies have been grouped together in the area of informal science education. Four of these dealt with museums, one with zoos.

Museums

Cognitive and affective outcomes of a class visit to a participatory science museum were examined by Flexer and Borun (88) by comparing responses of 416 fifth and sixth graders randomly assigned

to four conditions (control, exhibit only, lesson only, and exhibit followed by lesson) and two tests (verbal and visual). Students visiting a simple machines exhibit scored higher on a test of science content than did the control group, but lower than the group attending a classroom lesson in the museum. The study did not demonstrate conclusively a cognitive advantage of having the exhibit experience prior to the lesson. Scores on the visual test were consistently higher than scores on the verbal test. Study findings indicated that the particular strength of the science museum exhibit lies in the affective domain. Students found the exhibit much more enjoyable, interesting, and motivational than a classroom lesson.

Koran, Morrison, Lehman, Koran, and Gandara (148) investigated factors involved in attention and curiosity in museums. The findings were consistent with considerable curiosity research, indicating that both children and adults are attracted to novel as well as complex stimuli which can be manipulated in both formal and free-choice environments. Their data also support the growing movement to hands-on classroom activities from the perspective of attention attracting and holding power and curiosity evoking characteristics.

Lehman and Lehman (164) investigated the relative effects of experimenter and subject generated questions on learning from museum case exhibits. Fifty-five undergraduate education majors were randomly assigned to one of three treatment conditions as they entered the "walk-through" cave exhibit at The Florida State Museum. Subjects in treatment I received set induction materials directing them to enter the cave, to observe the cave carefully, and finally to read the information in five case exhibits after exiting the cave. Subjects in treatment II observed the cave exhibit, read the information in the five case exhibits, and answered two experimenter generated questions about each case exhibit immediately after reading the information in it. Subjects in treatment III observed the cave exhibit, read the information in the five case exhibits, and generated two questions about each case exhibit and answered them immediately after reading the information in each exhibit. All subjects received a posttest. Subjects who answered the experimenter generated questions performed significantly better than did subjects who did not answer any questions. Although no other differences were detected at the 0.05 level, the trend of results indicated that subjects who answered experimenter generated questions performed better than subjects who generated their own questions. These latter subjects performed better than subjects who read the case exhibits without answering any questions.

Stankiewicz (271) examined the effects of an advance organizer on the ability of randomly selected groups of seventh and eighth grade science students to recall and apply facts after a visit to a science museum. The experimental group was treated with an advance organizer composed of a series of activities developing the major concepts involved in a specific museum exhibit in a more general and abstract fashion than they were presented in the museum exhibit. The control

group was asked to help evaluate the museum exhibit after their visit. The mean score on the recall and application questions for subjects using the advance organizer were significantly higher than were the control group scores. Also, males scored significantly higher than did females.

Zoos

To test the concept that education is one important role of zoos, Churchman (50) reported on the works of teams of graduate students who conducted six different research projects using nonreactive methods to investigate selected behaviors of recreational visitors at the Los Angeles Zoo. The projects focused on: (1) visitor turning preference in walking through a zoo; (2) determinants of the holding power of zoo exhibits; (3) sign reading at two zoo exhibits; (4) children's reaction to selected animals in a petting zoo; (5) animal stereotypes; and (6) intergenerational communications. The studies contributed to knowledge of the educational impact of zoos and the development of nonreactive research methods.

Summary

With so few studies, no generalizations are justified. The potential for learning science in such informal settings, however, seems high, particularly from a motivational point of view. This is an area that is deserving of additional research and study.

Specific Interests

Introduction

A total of 32 studies have been grouped in this category. The two major subgroups constitute quite different areas of concern: energy education and females in science.

Energy Education

The ten studies in this category are reported in the two areas of status studies and implementation of energy education.

Status

The domain of energy education was reviewed by Morrisey and Barrow (198) to provide science educators with pertinent information about recent developments, issues, and trends in energy education. The review illustrated the lack of uniformity on what energy education is considered to be by educators. However, there seems to be consensus that energy education is an interdisciplinary area. Also, energy educators have tended to ignore other regional and national curricula efforts. It seems that most energy educators have preferred to "reinvent the wheel." State/regional emphasis has permeated energy education curricula and has interfered with the consensus needed to develop a national energy education curriculum. Research has been undertaken to determine students' and teachers' attitudes toward and knowledge about energy concepts. Studies show that well-designed educational interventions can have a noticable effect on students' and teachers' attitudes and knowledge with respect to energy concepts. In order to prepare teachers with skills for teaching energy related topics, energy inservice programs have been funded by NSF, Department of Energy, and many local agencies. Overall the workshops seem to have significantly increased the energy knowledge base of teachers but with inconsistent attitudinal change.

The Test of Energy Concepts and Values (TECV) was developed by Holden and Barrow (127) to assess knowledge about attitudes towards energy for grades 9-12. The TECV, a modification of the Energy Knowledge and Attitudes Test, consisted of 35 knowledge and 39 attitude items. The reliability for the attitude and knowledge sections was 0.70 and 0.76, respectively. Factor analysis was done for the attitude and knowledge sections separately. Item comparisons showed that TECV students responses were very similar to the young adults' responses to the National Assessment instrument.

Koballa (146) used a nine-step process as a multilevel screening mechanism in developing a Likert-type scale that measures that attitudes of teachers toward energy conservation. Initial validity data suggested the scale to be a valid measure of preservice teachers' attitudes toward energy conservation.

The purpose of a study by McCarley (178) was to assess and evaluate the status of energy education in the state of Alabama. Specifically, the study dealt with personal characteristics of the secondary school science teachers along with school characteristics, and whether or not these characteristics related to teaching energy education, topics, methods, and procedures used in existing energy education programs. The sample consisted of 400 randomly selected secondary school science teachers in the state of Alabama. Two hundred and forty-five questionnaires were returned. The major findings were: (a) the sex, age, number of years of teaching experience, level of certification, and current enrollment in an advanced degree program were not related to the teaching of energy

education; (b) the academic major of the teacher and the subject taught related to the teaching of energy education; (c) junior high science teachers used more varied teaching strategies than did the senior high science teachers; (d) the primary method of instruction was by integration into appropriate units; and (e) energy education was taught from one to ninety-nine days, the mean number of days was 16.

Implementation Efforts

The objectives of a study by Ulmer (293) were to: (1) measure student and teacher attitudes and behaviors toward energy conservation; (2) measure the teacher's "stage of concern" about energy education as an innovation; and (3) use student energy attitude scores as part of an intervention strategy designed to increase teacher search behavior for alternatives to existing curriculum materials. Forty-two secondary science and social studies teachers from 11 high schools in Lincoln and Omaha, Nebraska, administered the Youth Energy Survey to their classes (n=3,129). (1) Comparison of 1981 student energy attitude scores with 1979 scores showed more positive scores on five scales, more negative scores for one scale (nuclear energy), and no change on three scales. (2) Teacher attitude scores were more positive than were student attitude scores. (3) There appeared to be little or no relationship between teacher and student energy attitudes. (4) Teachers with impact concerns about energy education had the most positive attitudes; teachers with self concerns about energy education had the most negative energy attitudes. (5) The ratio of request/no request responses for energy education materials was uniformly consistent across all teacher concern states. Three out of four teachers in the study requested no energy education materials. (6) Teacher "search behavior" for alternatives to existing curriculum materials was significantly increased when the Youth Energy Survey was administered to classes and the results of the survey returned to teachers.

Koballa (145) tested the effect of a one-sided and two-sided persuasive message on the attitudes toward energy conservation of 85 preservice elementary teachers categorized as developmentally or non developmentally advanced with respect to the message. Two-sided communication was more effective regardless of the subjects' level of developmental advancement when attitude change was measured immediately following the treatment. Positive attitude change dissipated four weeks after exposure to the two-sided communication for both groups. While the attitudes of nondevelopmentally and developmentally advanced subjects exposed to the one-sided communication did not change immediately after exposure, the nondevelopmentally advanced subjects exhibited a positive shift in attitude four weeks following the presentation of the communication.

Lawrenz (154) compared the effectiveness of two types of inservice training offered through the Arizona Portal School Program. Both methods were designed to provide teachers with positive attitudes toward activity-centered energy education. The methods differed in length and energy-related content with one course running for 5 sessions and the other for 15 sessions. The longer course placed more emphasis on content knowledge. Three types of attitudes were assessed: attitudes toward curricular change, opinions on energy concepts, and beliefs about science education. Although the longer course had a more positive effect on the participants' views of and willingness to participate in curricular change and the shorter course had a more positive effect on the participants' views of teaching activity-oriented science, both courses produced the same type of change in the participants' views of energy issues.

Bitner (29) investigated the impact of two Department of Energy (DOE) summer energy education workshops conducted at the University of Maine at Orono during the summers of 1980 and 1981, on the 67 DOE participants and the impact of the local inservice energy education workshops, conducted by the DOE participants, on the 67 peer teachers, one selected by each DOE participant. It was found that the DOE participants included significantly more energy education topics in their 1982-1983 school curriculum, used significantly more business or industry produced energy education materials and self-produced units or materials, and utilized both the unit within a course and the separate course curricular designs signficantly more than did the peer teachers.

A study to compare the effectiveness of using guided-design versus traditional approaches to study the energy problem in America was conducted by Goldberg and Shuman (100). In guided-design, students spend much of their class time in small groups working on projects requiring them to make decisions about science related issues and problems. They are led through the decision-making process systematically by using printed instruction feedback materials prepared in advance by the instructor. Student performance was evaluated using unit exams and surveys. Goldberg and Shuman found that students can be helped to learn about the energy problem using lectures and laboratory experiences, but additional benefits were obtained by having the students work through the guided-design project. The guided-design students seemed especially motivated to learn the material. They appeared to rely less on the instructor. Guided-design students were better able to discuss their views on aspects of the energy problem and to support these views with factual information.

Summary

At this time, there appears to be no consensus as to what constitutes, or what should constitute, energy education. In most cases energy education appears to be considered interdisciplinary in

nature and is being integrated or incorporated into the existing curriculum. Most of the current research is concerned with attitudes and attitude change.

Females in Science

Introduction

The 22 studies in this area are grouped into (1) Elementary School; (2) Junior High School; (3) High School; (4) University; (5) Gradewise Comparisons; and (6) Historical Perspective. Eighteen of the 22 studies deal with secondary and/or college students.

Upper Elementary

Smail and Kelley (259) selected 2065 eleven-year-olds entering their first year of secondary school from a total of 10 schools and gave them a number of attitude and achievement tests during their first term at school. The test battery included three cognitive tests (science knowledge, spatial visualization and mechanical reasoning), and single measures of socio-economic status and general ability. There were also three attitude questionnaires, two sex stereotyping inventories, and a home background questionnaire. All tests were administered by teachers during normal lesson time. Girls and boys were found to be approximately equal in science knowledge. Boys did slightly better in tests of physical science, especially when these were in multi-choice form, but otherwise there were few sex differences. Neither the style of the question (multiple-choice or structural) nor the content (feminine or masculine) had great effect on sex difference in performance. However, boys performed markedly better than did girls on the tests of spatial ability and mechanical reasoning. These skills may be important for later success in technical studies at school. Attitudes toward science were virtually unrelated to achievement in science and technology-related areas. One important exception to this is that girls who saw science as masculine tended to perform worse on the cognitive tests.

Junior High

To assess the developmental relationship of perceptions of self-concept and gender role identification with adolescents' attitudes and achievement in science, a two-year longitudinal study was conducted by Handley and Morse (109). A battery of instruments assessing 16 dimensions of self-concept/gender role identifications was employed to predict students' achievement and attitudes toward science. Specific behaviors studied included self-concept in school

and science and mathematics, attitudes toward appropriate gender roles in science activities and careers, and self-perceptions of masculine and feminine traits. One hundred and fifty-five adolescents enrolled in the seventh and eighth grades participated in the study. Results indicated that students' self-concepts/gender role perceptions were related to both achievement and attitudes toward science, but more related to attitudes than to achievement. These relationships became more pronounced for students as they matured from seventh to eighth graders.

The purpose of a study by Erb and Smith (80) was to measure attitudes of adolescents toward women in science careers. To do so, researchers in the Career Oriented Modules to Explore Topics in Science Project validated a 27-item instrument, the Women in Science Scale (WiSS). The scale had high reliability whether measured by estimates of internal consistency or test-retest reliability. The validity was established using the known groups and correlated procedures. The test clearly distinguished between known groups and resulted in the predicted pattern of correlations with measures of other constructs. Erb and Smith concluded that the WiSS could prove to be a valuable instrument for basic research or curriculum evaluation where adolescent attitude toward women in science careers is a variable of interest.

High School

A five-year longitudinal study involving 3000 children in 23 secondary schools in an attempt to highlight the reasons for sex differences in science was begun by Harvey and Wareham (115). The sample consisted of: 1) all boys' schools; 2) all girls' schools; 3) mixed schools with mixed science classes and; 4) mixed schools with single sex science classes. To eliminate teacher effects one study investigator did the testing. The investigation consisted of a demonstration lesson and then a test and choice of optional practice experiments. This investigation clearly showed no sex differences with regard to practical work at the end of the students' first year at secondary school. The only sex difference that did emerge was in choice of activities. Girls rated chemistry and biology activities more highly than physical science activities. No significant differences were found between the different schools or between groupings of children.

Levin and Fowler (167) collected and analyzed data on sexual differences in secondary school students' attitudes towards science. Attitudinal differences were also analyzed for the independent variables of science programs and grade levels. Data were collected from 988 students using a modified version of the Fennema-Sherman Mathematics Attitude Scales to represent attitudes toward science. Multivariate analysis of variance was used to analyze the data for the main and interaction effects of the independent variables of sex,

grade level, and science program. Significant differences were indicated for all main effects. Interaction effects were not found. Females evidenced a significantly more positive attitude than males on three subscales. Eleventh graders evidenced significantly more positive attitudes than did tenth graders and twelfth graders. Positive attitudes decreased from advanced placement to terminal programs. Academic students did not differ from general students; however, they were significantly more positive than were the terminal students. General students were also significantly more positive than were terminal students except on the three subscales.

To provide some objective data regarding teacher response to pupil sex, an investigation was undertaken by Spear (265) to determine whether or not secondary science teachers display sex bias in their subjective evaluations of the written work of pupils. Two hypotheses were tested: (1) for identical written work, science teachers award higher marks to boys than to girls; (2) based on the evidence of written work, science teachers form higher expectations for boys than for girls. The sample consisted of 55 males and 25 females with 11 comprehensive schools represented. The procedure required teachers to evaluate six samples which had originally been provided by three boys and three girls. Each sample was presented to half of the teachers as being the work of a girl and to the remaining teachers as being the work of a boy. None of the teachers guessed the real aim of the investigation. On the basis of mean grade for each item on each individual work sample, a higher mean rating for "richness of ideas" in all six samples were attributed to boys. Additionally in all six samples, a "boy" author was judged to display greater interest than a girl author. Work attributed to boys also received higher mean rating for "scientific accuracy", "organization of ideas", and "conciseness" in five of the samples. "Neatness" was the only work characteristic in which girls were favored.

Campbell and Connolly (41) compared gender differences among Asian and Caucasian high school students enrolled in advanced science and mathematics research classes. Two explanations are discussed: (1) females elect fewer advanced mathematics courses in high school and college, and are thus prevented from entering technical-scientific fields; and (2) large sex differences exist in specific innate abilities. The study involved 27 high schools with a typical numbers of Asians and/or females enrolled in advanced science and mathematics courses. A questionnaire was given to 209 Caucasian and 78 Asian students, followed by interviews with 39 students. Asian students of both sexes devoted much more time to studying and research activities. Asian students tended to retain the attitudes and values of their former countries, were more influenced by peers and others to achieve, and were more competitive than Caucasian students. Asian females read more technical books and knew more computer languages, while Caucasian females emphasized socialization. Both sets of females tended to have lower positive attitudes toward themselves, while American males had many negative perceptions of gifted females in their classes.

Smith (258) sought to identify and relate those variables that had affected young women's career choices. A questionnaire was administered to an intact population of 371 high school females in public and private schools. Results showed that the existence of a role model had the strongest positive relationship with the respondent's having known someone in the same career in science. It was concluded that having a personal knowledge of an individual in the respondent's chosen career served as a modeling function for the individual. Mothers of respondents who had identified a role model were more likely to have had a negative attitude. Parents were frequently identified as being most influential in the career decision.

Kelley, et. al. (140) reported on an action-research project to improve girls' achievement in science and technology and investigated the reasons for their underachievement. The project followed a cohort of students in eight coeducational comprehensive schools from the time they entered secondary school until they made their option choices at the end of the third year. During this time, project staff worked with teachers to devise and implement strategies to reduce sex stereotyping. Among these strategies was a program of visits by women working in technical fields, posters and worksheets about women's contributions to science, curriculum development to produce female-oriented materials, and career advice linked to option choices in schools. Results indicated that the project was successful in refining the understanding of girls' and boys' attitudes and stereotypes about science and the process of option choices. The specific focus of interventions was the stereotyping of science and technology as masculine, and in this respect the children's attitudes were considerably modified. However, children's option choices were less susceptable to interventions. In addition, some teachers' attitudes altered in the desired direction.

A report by the National Association of Biology Teachers (201) presented to the National Science Board Commission on Pre-College Education in Mathematics, Science and Technology described a nine-month, nationwide project which investigated the teaching strategies and teacher attitudes which successfully encouraged girls in science. Subjects included 205 females and 147 males from seven high schools. In addition to analyzing instructional techniques, classroom climates, and teacher-student interactions, a selected sample of former as well as current students received a variety of instruments which assessed attitudinal, cognitive, and sociocultural variables. Results obtained indicated that teachers who successfully encouraged girls in science maintained well-equipped, organized, and perceptually stimulating classrooms, were supported in their teaching activities by parents of their students, were respected by current and former students, used non-sexist language and examples, included information on women scientists, used a variety of instructional strategies, stressed creativity and basic skills, and provided career information.

Matyas (177) conducted a study of exceptional secondary school biology teachers to determine what factors might be important in encouraging young women to remain on the "science track" during high school. Three questions were examined: (1) Males often score more positively on measures of science attitudes, interests, and past experiences. Would students of these teachers demonstrate similar sex-based biases? (2) Would the student's race/ethic group and school type/location have significant effects on these variables? (3) How are these variables related to science and engineering career interests among male and female students. Measures of students' science anxiety, attitudes toward science and scientists, cognitive style, locus of control, spatial visualization ability, participation in science activities, self-estimate of grade ability, and attitudes toward women in science were taken. Results indicated that the best predictor of science career interest for females was positive feelings about science classes. Females expressed less confidence in their scientific and problem-solving abilities and reported less frequent participation in curricular and extracurricular science activities than did males.

University

Baker (22) sampled 180 majors at a large eastern university to test the hypothesis that women who major in the sciences are expected to be more androgenous than women who major in a non-science field. Nearly all subjects were Caucasian and between the ages of 18 and 21. The Personal Attributes Questionnaire (PAQ) was used to determine whether the subjects had stereotypical characteristics of masculinity, femininity, or androgeny. Results indicated there were differences in the number of males in each PAQ category across majors. There were more non-science majors classified as feminine than women in science and more women in science classified as androgenous than women in a non-science major. There was no difference in the number of biological and physical science majors classified as feminine.

Lips (168) reported the findings of 446 female university students who had completed at least five courses and had been tested for self-schemas in mathematics/science ability. One hundred eighty-four of the women had taken or were taking more than the required one basic mathematics or science course. It was found that 35 percent of the women in the sample could be classified as having a negative self-schema for mathematics/science ability if they had taken or were taking mathematics or science courses. Findings suggested that many university women avoid mathematics and science courses not because of a sense of inferiority with respect to their abilities in these areas, but simply because of a lack of interest.

Arrick (16) reported the persistence of women and men science majors at an urban state university. Tinto's model of dropout behavior was the source for the background and institutional variables

measured. Bem's research on gender identity provided the basis for determining whether differences between women and men in gender-related attributes and socialization experiences were related to persistence factors. From a total population of 189 science baccalaureate degree recipients, 100 subjects were selected randomly. Respondents (34 women, 39 men) completed the NCHEMS Program-Completer and Graduating-Student Questionnaire and the Bem Sex-Role inventory. Additional questions tested Tinto model variables and examined gender-related phenomena. Results indicated that women and men completing traditional male-dominated majors were more alike than different in persistence factors. Shared academic experiences in the School of Science appeared to dominate over stereotypical differences, fostering similar cognitive and affective outcomes for women and men. The most significant differences between women and men were demonstrated by the character of their responses to the Bem Inventory and to questions about families and careers. The belief that social norms are changing for women was not varified. Rather, the women graduates appeared to have retained traditional gender-role expectations regarding educational and career aspirations as well as family plans.

Wittig, Sasse, and Giacomi (313) addressed two sets of theoretical and practical issues related to increasing the percentage of women engineers. First, the measurement of women's aptitude for, and changes in, skills during engineering training was assessed. Five cognitive skills tests were administered in a one-group pretest-posttest design to 24 baccalaureate women enrolled in an 11-month engineering training course. Significant increases in mechanical reasoning and spatial reasoning were shown on three of the five assessments. Scores on the mathematics anxiety scale and a measure of conservation of horizontality were also reported and showed the engineering females to be more mathematically confident than those in other academic majors. Second, the relationship of academic and demographic information and cognitive skills to degree of success in the program was reported. Pretraining spatial visualization scores predicted posttraining GPA group membership.

DeBoer (63) conducted a study to determine the importance of the transisiton between a student's initial collegiate science experience and the decision to continue in science, and whether the reasons students give to explain their success or failure in their first course are related to that decision. Attribution theory provided the framework for investigating these factors. The results showed that, for unsuccessful students, the plan to continue in science was unrelated to gender, mathematical aptitude, performance in the first science course, or attributions to luck, effort, ability, or task difficulty. For successful students, the plan to continue in science was directly related to attributions to ability, and inversely related to task difficulty. The results demonstrate the importance of a sense of competence for students who continue in science.

Gradewise Comparisons

Erickson and Erickson (81) investigated sex-related differences in science achievement from a science assessment project in British Columbia. Findings obtained from students in grades 4, 8, and 12 confirm earlier findings that boys outscore girls on items testing understanding and application of scientific knowledge. No sex-related differences on process skills were noted.

DeBoer (64) examined the high school and collegiate science and mathematics participation and performance of a group of students who graduated from a single highly selective liberal arts college in the late 1970's. It was also found that women took fewer science and mathematics courses than did men but performed at a higher level both in high school and college. It was found that students took fewer mathematics and science courses in college than in high school and that college performance and participation were related to performance and participation in high school.

Baird, Lazarowitz, and Allman (21) sought to answer two questions: (1) What are Utah junior and senior high school students' preferences and choices regarding science subjects? (2) Could preferences and choices be related to the type of school, age or gender? Two thousand students from grades six through twelve participated in this study. Findings showed that the zoology and human anatomy and physiology were most prefered. Ecology was least prefered. Preferences for topics in the physical sciences were also low. There was a trend among girls to prefer natural sciences such as botany while boys tended to prefer the physical sciences. Generally, students' choices were limited to those subjects presently taught in the formal school curriculum. They appeared unaware of the many science related subjects outside the texts or the approved course of study.

DeBoer (65) conducted a study which hypothesized that men and women develop a belief, during high school, about their competence in science that is based on their participation in certain science courses, their level of performance in those courses, and the effort they expended. Results indicated that although women performed very well compared to men in high school biology and chemistry, their participation and performance in science relative to that of men declined after that point. Also, women felt that they had worked harder than men did in high school science courses. Although they rated their ablity lower, actual performance was generally better. Results also showed that in a path model linking high school and college level variables, this sense of competence in science was a central variable. It was concluded that women's lower sense of competence in science is an important issue in their reduced participation in science courses and careers.

A study conducted by Welch, et. al. (303) investigated the attitudes of a random sample of 1,995 17-year-old students' toward women in science as indicated by responses to seven Likert items. Specific research questions addressed were: (1) What are the attitudes of secondary school youth toward women as scientists? (2) Are these attitudes different for males and females? (3) At what age do they originate? (4) What are some of the correlates of adolescents' attitudes toward the role of women in science? (5) What is the potential for such attitudes influencing science choices? Among the findings reported are those indicating that, in general, 17-year-olds expressed a positive attitude toward the role of women in science and that girls expressed significantly more positive attitudes toward women in science than did boys. Similar findings were noted when these results were compared to those of age group (and race).

Historical Perspective

A study by Arnold (15) used the technique of educational biography to determine how women gained a scientific education in the nineteenth century and what the consequences were in the lives of four Americans: Maria Martin Bachman (1796-1863), Almira Hart Lincoln Phelps (1793-1884), Louisa Catherine Allen Gregory (1848-1920), and Florence Bascom (1862-1945).

Summary

The research reported continues to show some evidence that males frequently outperform females with respect to knowledge and achievement in science, in spatial ability and mathematical reasoning, and in positive views of their own competence in science. It should be noted that these results are as likely to be societally related as to be gender related. There is, in fact, evidence that in cases in which females tend to regard themselves as less competent in science than males, their actual performance may exceed that of males. Females continue to favor the natural sciences while males favor the physical sciences. The evidence also suggests that science is still generally stereotyped as being masculine in nature. It appears that selection of a science related career is strongly related to the students' own sense of competence and, especially for females, to the presence of a role model. The majority of the research reported this past year related to the secondary and college levels, yet it is clear that attitudes are being formed well in advance of these years. Obviously, more work is needed at the elementary school level if these conditions are to be changed.

Preservice Teacher Education

Introduction

Sixteen studies are reported in this section although one of these (involving the use of technology) involves in-service teachers. The majority of these studies have preservice elementary teachers as their subjects, probably because students are available in greater numbers in elementary science methods courses than in secondary science education classes. Studies continue to be focused on teachers' attitudes, on personality characteristics as these may influence the teaching of science to elementary school pupils, and on teachers' concerns, among other topics.

Teacher Characteristics

Cognitive

Garnett and Tobin (96) sampled 299 preservice teachers enrolled in the second year of a teacher education program to investigate the extent and nature of reasoning limitations in preservice teachers so that programs can be designed to improve reasoning ability. Formal reasoning ability was assessed by using the Test of Logical Thinking. The results indicated that large numbers of preservice teachers do not use formal reasoning patterns when attempting to solve problems dealing with proportional reasoning. Since the test items use reasoning patterns students use in science investigations, Garnet and Tobin concluded that teaching effectiveness would be less for teachers who are unable to use formal reasoning to formulate appropriate questions and explanations in activity-oriented science lessons.

A nine item questionnaire was designed by Zeitler (327) to obtain information from preservice elementary school teachers about science courses they had taken at the secondary school and college level, their conception of purposes of science at the elementary school level, and their concerns about teaching children science. Copies of the questionnaire were sent to science methods instructors with 229 responses received. Results indicated that preservice teachers have a limited science background, especially in the earth and physical sciences. Teaching science information was the purpose listed most frequently while the teaching of science processes was low priority. The greatest concerns were about teaching children science content. An implication suggested by this study is that science content background was inadequate, with little promise of improvement. Improvement in this area may be a function of improved advising, and alterations in the preparatory program and science courses consistent

with the needs of elementary school teachers. Attention at the preservice level must be directed to the instruction of methodology and the vital role science plays in current society.

Devore (70) tested 45 preservice elementary school teachers (5 males and 40 females) at the beginning of their science methods courses to determine their science process skills, field dependence-independence, dogmatism, propositional logic ability, background in science, and age. The data indicated that field-independent and open-minded individuals had significantly better command of process skills than did their more field- dependent and closed-minded counterparts, and the propositional logic ability and science background were not as strongly related to process skills as were the two cognitive styles. This study supports the assertion that certain cognitive makeups are associated with ability in science and, perhaps, reflects that the type of science to which most elementary science teachers are exposed does little to prepare them to understand science or to teach how science works.

Reese (228) compared the results of two questionnaires in which students were asked to recall their elementary school science experience. The first survey was done in 1977 in which 180 second- and third-year education students of approximately the same age and at the same level of education completed the same questionnaire. Retrospective ratings made by the second survey students were more favorable with students reporting more emphasis on concept-oriented and process-oriented than on facts-oriented approaches. Students favored the process-oriented over the concept-oriented approaches.

Devore (71) assessed the relationship of cognitive level, three cognitive styles, and achievement in science to attitudes toward science and science teaching held by elementary school teachers. Subjects were elementary school teachers enrolled in nearly identical inquiry-oriented science methods courses at Rutgers University and the University of Utah. Subjects were tested before and after the course with an attitude scale. Subjects were also tested for field-dependence, tolerance for ambiguity, dogmatism, cognitive level, and science achievement. In addition, background information about the subjects were collected. Data revealed that the groups started out with equivalent attitudes, both made significant positive gains but the Utah group made significantly greater gains. The Utah group was significantly different from the Rutgers group with respect to cognitive style and level, and achievement in science, but these differences did not satisfactorily account for the differential gains in attitudes. Different variables were related to attitudes for the two groups. Dogmatism was a significant predictor of pretreatment attitudes toward teaching for the Utah group, and field-dependence was a significant predictor of change in attitudes toward science for the Rutgers group. This study indicates that (1) students have more positive attitudes toward science and science teaching after they have

been exposed to an inquiry- oriented science methods course, (2) the cognitive and achievement variables investigated are related to attitudes and attitude change, but the majority of the variance in attitudes remains unexplained, and (3) change in attitudes during an inquiry-oriented science methods course is more closely related to the cognitive variables than to achievement in science.

Affective

Psillos, et. al. (221) investigated the self-esteem as physics teachers of students taking preservice physics teacher education courses before and after the courses. The two physics courses selected were an inductive course, in which practical peer-teaching sessions preceded the teaching of theory, and a deductive course, in which the peer-teaching followed the theory sessions. There were 26 subjects in the deductive group and 24 in the inductive group. To measure student teachers' self-esteem, the Self-Esteem as a Physics Teacher (SEPT) instrument, a semantic differential test was given to students in both groups at the beginning and end of the course. The same test was also given to physics students not enrolled in the education courses as well as to the students who had subsequently dropped the course. There was no difference in self-esteem between students taking the education courses and those not choosing the education option. The students who dropped out of the courses had lower self-esteem than the other students. There was some evidence that learning theory enhances self-esteem if it takes place after practical teaching experience but has the opposite effect when presented before any practical teaching experiences.

Westerback (305) compared levels of anxiety about teaching science in preservice elementary teachers enrolled in science courses from 1977 to 1981 and found anxiety decreased in recent years. Initial anxiety about teaching science was high and changed in a positive direction in all years. Variations from year to year were attributed to staffing arrangements, grading practices, and course sequences.

Haury (116) examined a new construct, the Science Locus of Control (SciLOC) orientation, as a predictor of attitudes toward science teaching among 108 preservice elementary teachers. It was postulated that each person holds beliefs regarding the degree of his or her personal control in situations where decisions, actions, or other modes of performance require either the application of scientific knowledge or the employment of inductive or deductive reasoning skills associated with scientific thinking. These beliefs give rise to behaviors, including expressed attitudes, which reflect the control orientation. Multiple regression analysis was employed to demonstrate that up to 47 percent of the variance in expressed attitudes toward science teaching could be explained by SciLOC

orientation. Further analysis indicated that up to 42 percent of the variance in SciLOC orientation could be explained by differences in quantitative comprehension, sex, age, father's occupation, ethnicity, and high school size. These results are interpreted as evidence that SciLOC orientation is a major contributor to expressed attitudes toward science teaching among preservice elementary teachers and that it is influenced by a variety of factors related to academic and cultural experiences.

London (172) examined aspects of the affective component of literacy in science of Jamaican pre-service elementary teachers. The study was designed specifically to examine the attitudes of pre-service elementary teachers toward science and science teaching at each year in their program of studies and to compare these attitudes with the attitudes of a selected sample of inservice teachers. The relationship between attitudes toward science teaching and selected demographic variables was also investigated. The sample consisted of 296 pre-service teachers and 72 inservice teachers. The following findings were reported: (1) Third year students and in- service teachers exhibit significantly more positive attitudes toward science teaching than did first and second year students. (2) Significant positive relationships existed between attitudes toward science and attitudes toward science teaching. (3) Variables found to be significantly related to attitudes toward science teaching for the pre-service teachers included type of secondary schools attended, experience in science courses, gender, age, previous teaching experience, leisure time devoted to science, and science reading. (4) The only variable that was significantly related to attitudes toward science was science reading. (5) Strong predictor variables for attitudes toward science teaching, in rank order, were science reading, leisure time spent on science, type of secondary school attended, and previous teaching experience.

Methods Courses

Malone (176) assessed the effectiveness of conducting an elementary science methods course based on the Concerns Based Adoption Model (CBAM) upon the concerns and attitudes of preservice elementary teachers. Subjects were randomly assigned to one of three treatment groups. The three groups included a traditional science methods course, a course based on the theoretical development of concerns, and a course based on the actual measured concerns about teaching an elementary science methods course. Two instruments - The Stages of Concern Questionnaire and the Science Teacher Attitude Scale - were used to gather pretest, posttest, and delayed posttest data. Attitude toward science and science teaching improved and concerns about teaching science shifted from lower to higher stages of concern in all three treatment groups as predicted by Concerns Theory. However, none of the methods courses proved superior in affecting concerns or attitudes.

Saegert (243) sought to train secondary student teachers to teach using strategies compatible with the learning styles of pupils in their classes and attitude. Secondary science student teachers (n=16) and students (n=32) enrolled in the classes they taught participated in the study. Learning style profiles were obtained from student teachers and their students. Concerns information was collected from student teachers on three occasions: midway through student teaching, approximately two weeks later, and prior to completing student teaching. The attitudes of secondary science students toward their student teacher were measured midway through and at the end of student teaching. Information on students' academic performance was provided by student teachers and served as the measure of achievement. Results indicated that once concern for self and concern for the task of student teaching decreased, student teachers demonstrated a concern for the impact of their teaching and used greater variety in their teaching strategies, a better match for students' learning styles. High impact concerns were found to be directly correlated with pupils' achievements. Moreover, the directness of the teaching strategies used by the student teacher was found to be correlated with pupils' achievement.

A study by Al-Eyoni (9) examined how the current science programs at junior colleges in Saudi Arabia meet the needs of elementary science teachers by surveying opinions of science faculty and prospective elementary science teachers. The following findings were reported: (1) Science faculty and prospective elementary science teachers had no significant difference in point of view concerning the competencies which should be included in the science training program. (2) A significant difference in point of view existed regarding the success of the current science program. (3) No significant difference was found concerning the importance of methods of instruction. (4) A significant difference in point of view existed concerning the abilities of prospective elementary science teachers to use selected methods of instruction in their teaching.

Resources

Barrow (23) compared elementary science educational library resources in New England graduate and undergraduate teacher education institutions using a 31-item survey instrument developed for library directors. Data were obtained from 62 institutions with certified elementary education programs. Among the findings reported are: (1) inadequate resources, except for fiction science trade books, at undergraduate institutions and science reference books at both undergradute and graduate institutions; (2) a severe lack of computer software at both institutions; and (3) Science News was the only science education journal available in more than 60 percent of the undergraduate institutions. In addition, more than 75 percent of the surveyed graduate institutions had Education Index, CIJE, RIE, and

Dissertation Abstracts, while only Education Index was available in more than 75 percent of the undergraduate institutions. Findings illustrate the need to improve the science education resources, journals, and support resources at New England teacher education libraries.

Technology/Microcomputers

A study to determine whether differences existed between the microcomputer implementation process of inservice teachers who were participating in workshops and inservice teachers who were not engaged in professional development activities and were not presently concerned about microcomputer use was investigated by Beall and Harty (26). Also investigated was the potential influence of the demographic or background characteristics of the teachers in both groups on microcomputer implementation process. There were 31 inservice teachers used in the GO-group (interested, motivated in implementing microcomputer activities) who had volunteered to participate in a series of inservice workshops. There were 31 in the NOGO-group (identified by their principal as not being interested in microcomputer implementation or engaging in professional development activities). A study-specific instrument, "Inservice Teacher Microcomputer Process Scale" was developed to gather information on teacher reaction to microcomputers. The GO-group teachers were found to be more optimistic toward new ideas and instructional projects, more willing to try something new even if extra effort was required, more willing to assist in the development of microcomputer instruction than the NOGO-group. GO-group males were more enthusiastic about their willingness to assist, more confident, and had greater implemental processes than had females. NOGO-group females were more positive with respect to their disposition toward new ideas and developments in microcomputer instruction.

The purpose of a study by Wesley (304) was to determine the effects of computer-assisted instruction (CAI) versus a text mode of programmed instruction (PI), and the cognitive style of locus of control, on preservice elementary teachers' achievement of the integrated science process skills and computer literacy. Eighty-one female preservice elementary teachers in six sections of a science methods class were classified as internally or externally controlled. The sections were randomly assigned to receive instruction in the integrated science process skills via a microcomputer or printed text. The study used a pretest-posttest control group design. No differences were found between achievement of the integrated science process skills or computer literacy of individuals receiving the CAI and printed PI treatments. Additionally, no differences were found between internally and externally controlled individuals in their achievement of the integrated science process skills or computer literacy. However, a significant ($p<0.05$) aptitude by treatment interaction was found. Differences in adjusted posttest scores of

externally controlled individuals favored the CAI mode. There were no differences between treatments when internally controlled subjects were considered.

Battista and Krockover (25) investigated the effects of computer use upon the computer literacy of preservice elementary teachers using two methods of instruction: computer assisted instruction in an earth science course and computer programming in a mathematics education course. Computer literacy was measured by the Minnesota Computer Literacy and Awareness Assessment (MCLAA). For each component of computer literacy, differences in group posttest scores were used as the covariate. Pre- to post-test increases in scores for each group were also examined. The results indicated that the treatment given to the computer programming group had little or no effect upon the students' computer literacy while the treatment given to the computer assisted instruction group had a significant effect upon the affective subscale of the MCLAA. A positive effect was also indicated on the cognitive subscale of the MCLAA. They concluded that an effective method for improving preservice elementary teachers' computer literacy is to involve them in computer assisted instruction, possibly through a science course.

Summary

It is difficult to draw any conclusions from so varied a group of studies. Preservice teachers who are open minded and less dogmatic than their colleagues appear to have better command of process skills. Haury's (116) Science Locus of Control Orientation may serve as a major predictor of attitudes toward science teaching held by preservice elementary teachers but attitudes are also influenced by other factors. Can science methods courses influence attitudes? According to Devore's (71) research, inquiry-oriented methods courses help. According to Malone (176) methods courses based on teachers' concerns do not result in significant differences in concerns or attitudes.

Inservice Teacher Education

Introduction

Studies in this section have been grouped into four categories: (1) Teacher Characteristics; (2) Effects of In-service Training; (3) Implementation Issues; and (4) Foreign Countries. The size of these categories varies, with the implementation issues section containing 12 studies and the foreign countries section, two.

Teacher Characteristics

A study which investigated the extent of agreement between selected college level elementary science educators (n=107) and fourth-, fifth-, and sixth-grade Kansas science teachers (n=256) regarding the science laboratory teaching competencies that should be possessed by these teachers was conducted by Donaldson (72). Each group was given a questionnaire focused on operational, process, management, developmental, and evaluation items. Among the results reported are those indicating: that science teachers believe there is a somewhat greater need for competencies related to microscope use, cleaning glassware, and use of models; that science educators perceive a somewhat greater need (than teachers) for cultures in the classroom and for the use of keys (in identification), terraria/aquaria, the metric system, histograms, and electric circuits; that teacher educators regarded all science process competencies at a higher level of need than did science teachers; no differences between the groups for the management items; that hands-on approaches, individualized learning, and low budget or homemade materials were favored more by teacher educators than by teachers; and that teacher educators favored skill tests and checklists, student feedback instruments, and audio-tape techniques to a greater degree than did teachers.

McKinnon (185) investigated the relationship of selected teacher characteristics, to test their attitude toward science and science teaching, and to test their spatial ability. This study was also designed to investigate the relationship between the elementary science curriculum Science Curriculum Improvement Study (SCIS) and the above characteristics. The study population consisted of 76 Durham County, North Carolina, elementary teachers. Approximately one-half of the elementary teachers used the Science Curriculum Improvement Study program and the other half used a textbook program. The Differential Aptitude Space Relations Test, the Redford Attitude Toward Science and Science Teaching Questionnaire, and a researcher-designed questionnaire were used. The following information was determined by the researcher-designed questionnaire: teacher total years of experience, grade level taught, whether or not they used the SCIS program, and if so, for how many years and finally whether or not the teachers had undergone in-service training in SCIS. Findings indicated that: (1) There was a statistically significant relationship between spatial ability and attitude toward science and science teaching. (2) There was a statistically significant relationship between spatial ability of SCIS teachers and the grade level at which they teach. (3) There was a statistically significant relationship between the spatial ability of a SCIS teacher and their years of experience with the SCIS program.

Aikenhead (7) explored the decisions that science teachers make when they plan for instruction via a case study analysis of five teachers in a high school. The study probed into the personal reasons, beliefs, and dilemmas underlying their decisions. These

decisions, while serving many purposes, had a common structure which involved tradeoffs and compromises. The decisions represented the end result of the conflict between a cluster of teacher intentions and a melange of ideas about student characteristics. Teachers appeared to make decisions within a framework that holistically integrated science content and practical classroom knowledge--a knowledge system that includes the basic beliefs of a teacher and the socialization of students.

Wolfe (314) identified the evidence of the ideas about the nature of science to which elementary school pupils are exposed and the manner in which teachers provide for these ideas. She also developed a scheme based theoretically in the philosophy of science, paticularly in the work of Norwood Russell Hanson for the observation and analysis of classroom interaction--both teacher-pupil dialogue and science activities--as these occur during science lessons.

The purpose of research conducted by Conwell (57) was to examine the effects on achievement and attitude of the interaction between specific types of learners as assessed by The Myer-Briggs Type Indicator (MBTI) and science learning activities designed to correspond to MBTI types. A simplified model of the MBTI with four types was used: sensing-feeling (SF), sensing-thinking (ST), intuitive-feeling (NF), and intuitive-thinking (NT). Of the 96 elementary teachers who participated in this study, 56 were SF learners while the remaining 40 were non-SF types. Since the majority of teachers were of the SF type, the science activities that were matched to the teachers' type exhibited SF qualities. On the other hand, the science activities that were mismatched to the teachers type had characteristics of the NT type. The results showed that the activities that were rated as being well matched to the SF type received significantly more positive ratings by SF types than by non-SF types. Likewise, activities rated as extremely mismatched to the SF type receicved signficantly less positive ratings by SF types than by non-SF types.

Azencot and Blum (20) compared the performance of teachers and students on the Field Experience Achievement Test (FEAT) in Israel. The sample included 35 teachers who had no earlier experience with the study curriculum, and who took the test before and after the inservice course, 28 teachers who had inservice training and had already taught the study curriculum and 32 young university graduates in a science teacher preservice course. There were also 429 seventh grade pupils who had taken the FEAT during its development and validation. Results indicated that the tests developed to evaluate pupils' achievement in skills which are typical for a new curriculum can also be successfully used in teacher inservice training toward the implementation of that curriculum. Also, this investigation shows that teacher inservice training is often necessary before a new curriculum can be introduced.

Dyer (77) attempted to identify regional science inservice program needs of secondary science teachers in the Panhandle of Texas

as determined by perceptions of need by the teachers and their principals. The study employed a modified Delphi technique with data collected in two stages. Seventy-six teachers and 47 principals responded to the first questionnaire, a rank-ordering of 17 essential secondary science teacher competencies from a previous study among university science educators. Teachers and principals were in agreement on three of their five top-ranked topics: using effective laboratory activities, planning and organizing instruction, and using a variety of instructional strategies. The second stage of the investigation yielded 137 teachers' responses and 64 principals' replies. The most common types of activities preferred were sharing sessions, awareness sessions, and participatory sessions.

Attitudes of elementary teachers in Saudi Arabia toward teaching science in grades 4-6 were investigated by Al-Mansour (11). Significant positive correlations were found between attitudes toward teaching science and previous experience in teaching science in grades 4-6, nationality, years since initial training, and geographic location of the school. In a stepwise multiple regression formula only previous experience and nationality were found to contribute to the formula.

Al-Dubaiban (8) analyzed teaching behaviors of science teachers trained at the science and mathematics center in Dammam, Saudi Arabia, and found they: (1) spent 65 percent of their classroom time lecturing, (2) neither listened to students nor gave them an opportunity to make decisions, and (3) were non-rebuking teachers.

Effects of Inservice Training

Since the acquisition of extended wait-time is and has been a major concern in teacher education, an inexpensive, readily accessible wait-time training model was developed and validated by DeTure and Miller (69). In addition, the effects of extended wait-time on associated discourse variables (including repeated verbal patterns, question frequency and type, compliance moves, and reward patterns) were examined. A written protocol model was used as the training method for a group of 23 inservice teachers. Preservice teachers (n=23) served as the non-equivalent control group. Subjects taught a series of inquiry lessons, taped and analyzed the results according to procedures in the protocol. Results indicated that teachers could significantly increase their wait-time and could reach criteria (three seconds) in two sessions. In addition, the teacher-calculated wait-time did not differ significantly with a microcomputer pause analysis apparatus.

A subsample of ten teachers cooperated in a follow-up study, by Swift, et. al. (279), to investigate the effects of instructional guides and wait-time feedback upon the classroom interaction of teachers. After a workshop, weekly tape recordings of the

participants' classes were analyzed. Discussions with the teachers were held concerning effectiveness. Since only strengths and successes were emphasized, the process was labeled "supportive intervention." Over the four-week duration of the study, important changes in teacher-student interaction were observed. Teachers extended their wait-times to the three second minimum. There was an increase in student-student interaction and in length of student responses. Teachers asked greater numbers of divergent and evaluative types of questions indicative of higher levels of cognitive discourse in the classroom. Finally, the teachers responded in a highly favorable manner to the suggestions provided by members of the research team.

The purpose of a study by Chang (48) was to determine the effect of in-service training on teacher attitudes and teacher performance in their teaching of the new elementary science curriculum for grades one through five in Taipei, Taiwan. Sampled teachers came from 100 out of 120 public elementary schools in Taipei. Principals designated one teacher who had received three weeks of training in inquiry-discovery science teaching for comparison with another teacher who had not received training in this approach. It was found that experimental and control group teachers had the following similarities; (1) They had similar attitudes toward the rationale for inquiry-discovery teaching. (2) They had approximately equal performance in using of methods and techniques of inquiry-discovery teaching. (3) They had about the same performance in utilization of teaching materials, facilities, and resources in inquiry-discovery teaching.

Fraser-Abder (89) undertook a study to investigate the extent of science attitudinal change in elementary teachers (n=35) in Trinidad and Tobago during an activity-oriented science curriculum development workshop. The model used during the study attempted to incorporate some aspects of science content development, manipulative hands-on experiences, video-taping, development of self confidence, teach-reteach methodology, and supervisor, peer, and cognitive, and behavioral responses to elementary science teaching. Results obtained from a 27 item-instrument (measuring science knowledge, use of science equipment, interest in science, and apprehension about science teaching) indicated that the model was effective in producing the desired attitudinal changes in the four areas measured.

McFarlane (179) sought to determine the effects that specially developed science units and regular consultant contracts might have on the attitudes of primary elemenatry teachers. The Moore Science Teacher Attitude Scales (STAS) were used to measure teacher attitude toward science as a body of collected information and to measure teacher attitude toward the teaching of science. Twenty-nine second and third grade teachers responded to the scale items on three occasions: prior to the start of the 1981-1982 school year, eight weeks after the three-week treatment period and, finally, two months after the treatment period. The treatment effect was found to be not statistically significant. However, analysis of gain scores indicated

significant relationships between teacher attitude toward science teaching and the grade taught, building assignment, and teacher age.

Implementation Issues

Elementary

A longitudinal study which focused on the concerns of elementary school teachers who were involved in implementing the Science Curriculum Improvement Study (SCIS) curriculum was conducted by Loucks (174). Two major questions were addressed: (1) Do stages of concern exist?, and (2) if so, are they developmental? The sample consisted of teachers attending summer workshops in 1974 (n=15) and 1975 (n=38). Concerns were assessed five times (including before and after the training workshops) using the Stages of Concern Questionnaire (SoCQ), a Likert-type instrument developed to measure seven hypothesized stages of concern. The seven hypothesized stages are awareness, informational, personal, management, consequence, collaboration, and refocusing. Results indicated that individuals in this sample followed a general development trend from being more intense at the lower Stages of Concern to becoming more intense at the higher Stages of Concern and that management concerns never predominated in any group.

Lombana (171) investigated both methodological and program questions related to the implementation of an innovative elementary science curriculum intended to increase learner participation through hands-on activities. Fifty teachers attended a workshop and were subsequently expected to implement the curriculum within their classrooms. Results revealed that the workshop was an important factor which encouraged implementation. Both preordinate and emergent results indicated a more positive attitude toward teaching science. Factors which encouraged implementation were: workshop experience before implementation, flat-top desks, sinks located in rooms, complete set of materials, and procedures for keeping kits stocked. Variables that discouraged implementation were lack of materials, sharing of kits between more than two teachers, competition for instructional time from reading and math, slant-top desks, and preparation time involved for each lesson.

Crocker (62) described a replicated study of factors influencing implementation of a hypothetical elementary science curriculum. The instrument used allowed teachers to respond to a particular implementation scenario devised by combining a number of statements about properties of an innovation with school and teacher reactions to the innovation. Responses were given as estimates of the probability of implementation under the conditions described in the scenario. Results showed that the staff attitude factor was by far the most salient influence on implementation. An inservice factor which was

highly significant in one of the applications of the instrument failed to replicate. This suggested the possibility that context differences between the two samples may have been important for this factor. The findings were interpreted in relation to Fullan's model of implementation and to other research which highlighted the importance of individual interpretation of the properites of an innovation.

Hall, et. al. (108) reported various collaborative efforts involved in implementing a district-developed science curriculum. The findings are reported in four papers which discuss: (1) how a concerns-based adoption model was used to design staff development to support innovation implementation, (2) the quantitiative data collected form teachers throughout the study, (3) various school level influences, such as principal behaviors, and (4) the implementation, development and use of an achievement measure related to the innovation's goals.

New elementary science programs have often been noticed to fail at the stage of implementation. It was hypothesized by Chakagondua (46) that part of such failures stemmed from discrepancies which existed between the developers and teachers in their perceptions of new programs. The purpose of this study was to determine the developers' and teachers' perceptions of a new elementary science program; to examine agreements and disagreements in their perceptions; and to determine any congruencies or discrepancies between their perceptions and actual classroom practices. Results showed that there were no distinctive developers' or teachers' viewpoints, but that most of the respondents had similar viewpoints concerning the new program. A small group of teacher-users held a distinctive viewpoint of the established program, while the other viewpoints of the program were vague. The classroom data analysis revealed that the new program showed a higher congruency between perceptions and performances than did the established program. A few teachers were classified as non-implementers because they displayed an equal and insufficient number of distinctive characteristics for both programs.

Johns (137) asked Nevada elementary school teachers to rank order twelve obstacles to teaching science. Questionnaires listing the twelve obstacles were distributed among 40 elementary schools in a Nevada school district. Data were obtained from 272 returned questionnaires. A fifty-one percent response revealed a fairly uniform perception of the obstacles across the categories of sex, age, and grade. The results obtained locally did not appear to be materially different from those obtained in national surveys. Among the items found to be the greatest obstacles to the teaching of science were lack of inservice facilities, lack of supplies and equipment or the funds to purchase them, and inadequate room facilities.

A study to review several studies of inservice education that relate directly to elementary school science projects was conducted by

Orlich (209). Review of the studies indicated that because the financial burden is so great, a future trend will be to ask the people who take inservice courses to share some of the expense. Some criticisms of inservice projects revealed by the review were: lack of a planned systematic approach, lack of adequate funding, lack of relevance to perceived professional needs, and lack of direction. Studies of inservice projects involving metric achievement, year-long projects, one-day projects, noncourses, curriculum changes, and periodic maintenance indicated that inservice programs yielded higher student achievement scores and more effective teaching. Inservice science programs that use curricula that can serve as exemplars, provide hands-on experiences, use fieldtrips, are relevant to the jobs of the participants, and teach how to use the knowledge were identified as qualities of effective elementary science inservice programs.

Teters, et. al. (285) in collaboration with NSTA, conducted a survey during the 1982-1983 school year of 252 elementary teachers across the United States to determine the status of science teaching in their schools and to indicate what could be done to improve education. Principals distributed the questionnaire to K-6 teachers in their schools and returned them to NSTA. The most significant result of this study indicated that more life science topics are taught than earth or physical sciences topics. In the life sciences, more teachers teach characteristics of plants while fewer teach animal characteristics and human biology. The hands-on approach is used less in the upper grades, and most instruction, no matter what level, takes place in large groups and is demonstration-type instruction. The majority of teachers indicated that science instruction in their school could best be improved by providing them with science kits and teacher guides.

Secondary

Garrard (97) examined the effectiveness of the developmental project mehtod of producing secondary science curriculum materials by determining if the developmental process led to a science curriculum that addressed the goals and objectives of the project and if the developed curriculum materials enabled students who used them to perform better than did students using conventional science materials. This study was conducted by examining the processes, procedures, and outcomes form the School and Community Science, Technology, and Environment Project (S & C STEP) in Clarke County, Georgia. In general, the experimental materials were found to be more effective in enabling students to accomplish the goals and objectives of the project than was the conventional curriculum.

The focus of a study by Duschl (756) was an examination of two critical aspects of the scientific enterprise: science teachers and scientific theories. The purpose of the study was to assess the

degree to which teachers made decisions based on scientific theories. Two general findings were reported: (1) science teachers gave little consideration to scientific theories in their instructional task decision making and (2) instructional task decisions were dominated by (a) teaching propositional knowledge, (b) using select scientific processes as vehichles for teaching propositional knowledge, (c) teaching the objectives outlined in curriculum guides, (d) coping with pressures of accountability, and (e) humanistic ownership feelings toward the students.

A study by Thong (288) described how teachers plan and implement interdisciplinary studies programs. The study focused on teacher decision making and curriculum planning. A questionnaire was mailed to middle/junior high school teachers of the New York school systems; 41 were returned. Findings showed that the teachers: (1) planned and implemented interdisciplinary studies programs by way of units of study/minicourses; (2) confirmed the list of competencies/skills which included practicing pupil-teacher planning, employing the emerging needs approach, individualizing instruction, getting students involved in independent study; (3) confirmed the list of problems/difficulties which included time for individual and group planning, teacher and pupil schedules, space, teacher training and preparation; (4) confirmed the need for planning and instructional assistance that related directly to the improvement of instruction such as determining pupils' needs and interests, as opposed to assistance of a managerial nature such as permitting field trips; and (5) expressed favorable attitudes toward interdisciplinary studies programs.

Munby (200) described a qualitative study of the beliefs and principles of one science teacher. The study employed the Repertory Grid Technique of Kelly. This technique was illustrated by the case study. Segments from an interview with the teacher concerned were provided. Information obtained from working with this teacher was used to establish the dominant beliefs that she held. These beliefs were seen as important in terms of intructional innovation and implementation.

Foreign Countries

A descriptive study of some of the problems faced by technical advisors implementing projects for the improvement of science education in Africa and reasons for these problems was undertaken by Nichter (202). Documentary analysis of UNESCO in-house records of 12 secondary teacher training projects in nine countries was the principal method of research employed. Data were grouped into six descriptive categories. "Underestimating" was the highest among problems experienced by UNESCO science education improvement projects and strongly reflected the inadequacy of the infrastructural and financial capacities of host countries to meet the human and physical resource requirements of the project. "Underestimating the Process"

was the second ranked problem and appeared to be avoidable with more detailed realistic planning. "Financial," "Personality Conflict and Motivation" and "Opposition from Key Groups," were the other problems, ranked in the order given.

A study to analyze the process of curriculum development adopted by developers in language arts, biology, in a centralized educational system was designed by Peretz and Tamir (215). Specific objectives were to identify naturalisitc models of curriculum development used in curriculum projects in Israel, point out relationships between contextual factors (such as location of development teams in universities or the Ministry of Education) and the characteristics of the development process, and uncover elements of the personal, practical knowledge of the participants in the develpment process. Among the findings reported and discussed were those indicating that: (1) the average time of development of a project was three to five years; (2) almost all projects have engaged in formative evaluation ; (3) all projects were funded by the Ministry of Education; and (4) although organizational characteristics of individual projects varied, several modes of operation could be identified. One conclusion reported from analyses of the curriculum projects and from interviews with the curriculum developers was that there was not one naturalistic model of development; every project examined its own special blend of characteristics.

Summary

As with the preservice section, the majority of studies of in-service teachers involve those who teach science to elementary school students. there was not sufficient commonality among the characteristics examined to support any generalizations. When effects of inservice training were considered, instruction in wait-time does appear to be effective--if two studies are sufficient to such a statement. Implementation issues varied. They serve to make the variety of factors that need to be identified and dealt with when attempting to implement a science program or curriculum change.

Research Methodology

Introduction

The eight studies reported in this section represent a range of research methodologies, as is indicated by the fact that the eight studies fit into seven different categories.

Computer Methodology

Larkin and Rainard (152) described a research methodology (called information-processing psychology) for studying how people think. Its goal is understanding how people think while doing complex tasks. It uses detailed data, usually from individual subjects, and develops precise yet powerful models of human performance, often by using a computer. To illustrate information-processing research, two studies were described. The first showed how computer models are used to explain thinking. A computer program models the knowledge needed to understand and use a physics textbook. The second study showed how information-processing approaches can be used systematically but more simply. This study clarified why students find it so difficult to master the "factor-label" method for converting chemical units. The article concluded with a discussion of guidelines for using information-processing ideas.

Clinical Interviews

During the past several years interest in using clinical interviews to assess students' conceptual knowledge has increased. However, using clinical interviews when research questions require quantitative comparisons has been difficult. The central difficulty is to construct variables that can be used to quantify and statistically compare the results of interviews while maintaining exactly what student conceptions are associated with each variable. The purpose of an article by Finley (86) was to present a technique for constructing variables that overcomes this difficulty. The technique involved the representation of each proposition a student uses in terms of a standard set of underlying practices, concepts, and relationships among concepts. Each proposition represented in these standard terms can be used as a variable to quantitatively compare the knowledge of students as expressed in clinial interviews.

Time-Series

Farnsworth and Mayer (84) attempted to determine the degree of discrimination the time-series design allows in collecting data on achievement. A multiple-group, single intervention, time-series design was adapted to the collection of daily data on achievement of eighth grade earth science students on a unit on plate tectonics. Single multiple-choice items were randomly assigned to each of three groups of students, identified on the basis of their ranking on a written test of cognitive level. The top third, (formal) was compared on the basis of knowledge and understanding with the lowest third (concrete) to determine if the data collected in the design would discriminate between the two groups. Statistically significant differences were found between the two groups on both knowledge and

understanding levels of learning. These differences confirm the discrimination of the intensive time-series design. The time-series analysis model with a trend in the intervention was better than a model with no trend for both groups of students, in that it accounted for a greater amount of variance in the data from both knowledge and understanding levels of learning. This finding adds additional confidence in the validity of the design for obtaining achievement data.

Monk (194) examined three methods used to pool single-item-per-subject data collected in intensive time-series studies, to determine if method of pooling had an effect on subsequent data analysis. The methods examined were based on simple averaging, difficulty weightings of averages, and the application of the Rasch logistic model. Analyses were conducted which examined regression results obtained when the pooled scores of groups of students were regressed by day. Results indicated that the three methods of pooling did not differ significantlly after subsequent analysis, although the case was made that a pooling procedure based on the Rasch logistic model was the most heuristically sound.

Aptitude-Treatment Interaction

Koran and Koran (147) identified promising areas of aptitude-treatment interaction research in science education such as general ability, prior experience, and anxiety, and discussed research methods.

Qualitative Research

The shortage of qualified teachers, and the quality and quantity of the science taught in precollege institutions were two issues addressed by Spector (266). Spector delineated aspects of qualitative research having the potential of providing guidance to change agents in designing effective strategies to mitigate the crisis. A discursive approach to qualitative research involving the method of collecting and simultaneously analyzing data known as "grounded theory" was described. Role theory and schools as organizations composed of interactive subsystems were defined as suitable frameworks within which to analyze data.

Meta-Analysis

Willson (309) discussed the use of meta-analysis as a research method to describe bodies of research data. According to Willson it promotes hypothesis formation, the development of science education

laws, and plays a role in updating research. A procedure was presented using Bayesian analysis. The results showed how new findings complement the previous meta-analysis and extend its conclusions. Additional methodology questions addressed were how studies are to be weighted, which variables are to be examined, and how often meta-analyses are to be updated.

Attitudes

Shrigley and Koballa (250) examined uses of Likert-type attitude measures and concluded that science educators who design or modify science attitude scales should continue using item-total correlations and other quantitative techniques to test for emotional intensity, but qualitative judgments are necessary, too. In addition, the frequency distribution of data generated by each statement should be examined for skewness and high percentages of neutral responses, both of which can impair the emotional intensity of an item.

Summary

With the variation in types of methodologies, no generalizations can be drawn. Readers interested in specific examples are urged to refer to the original studies for more information.

References

1. Abeti, S. L. "The Relationship Between Social Environment in the Home and Achievement in Science - Uganda." African Studies in Curriculum Development and Evaluation. Nairobi, Kenya: Institute of Education, 1984. ED 250 154

2. Abimola, I. C. "A Study to Describe and Explain the Alternative Conceptions Related to Human Respiration Held by Selected Nigerian Form Four Students." Dissertation Abstracts International, 45(5): 1357-A, 1984.

3. Abraham, M. R. and J. W. Renner. "Sequencing Language and Activities in Teaching High School Chemistry - A Report to the National Science Foundation." Norman, OK: University of Oklahoma, 1984. ED 241 267

4. Adeniyi, E. O. "An Analysis of the Relationship Among Intended Curriculum, In-use Curriculum, and Students' Cognitive Structive Associated with an Ecology Unit." Dissertation Abstracts International, 44(9): 2662-A, 1984.

5. Aguirre, J. and G. Erickson. "Students' Conceptions About the Vector Characteristics of Three Physics Concepts." Journal of Research in Science Teaching, 21(5): 439-457, 1984.

6. Aiello-Nicosia, M. L. et. al. "The Relationship Between Science Process Abilities of Teachers and Science Achievement of Students: An Experimental Study." Journal of Research in Science Teaching, 21(8): 853-558, 1984.

7. Aikenhead, G.S. "Teacher Decision Making: The Case of Prairie High." Journal of Research in Science Teaching, 21(2): 167-186, 1984.

8. Al-Dubaidan, S. M. "Analysis of Teaching Behaviors of Science Teachers Trained at the SMC and Determination of Faculty Policies Toward These Bahviors in Dammam, Saudi Arabia." Dissertation Abstracts International, 45(1): 142-A, 1984.

9. Al-Eyoni, S. M. "A Comparative Study Between Opinions of Science Faculty and Prospective Science Training Program at Saudi Arabian Junior Colleges." Dissertation Abstracts International, 44(11): 3341-A, 1984.

10. Ali, A. "The Effectiveness of Laboratory Photomicrography for Studying Microbiology in Nigerian Secondary Schools." Journal of Research in Science Teaching, 21(1): 63-70, 1984.

11. Al-Mansour, A. M. "Attitudes of Elementary Teachers in Saudi Arabia Toward Teaching Science in Grades 4-6." Dissertation Abstracts International, 44(10): 3026-A, 1984.

12. Al-Ruwashid, M. S. A. "The Effects of a Lecture-Only and Lecture-Laboratory Approach on Riydah Junior College Saudi Arabia Chemistry Students' Achievement and Attitudes." Dissertation Abstracts International, 45(5): 1357-A, 1984.

13. American Chemical Society. "Task Force Frames Recommendations on Education." Chemical and Engineering News, 62(19): 34-37, 1984.

14. Anderson, S. C. "The Effects of Clinical Simulations on Error Rate, When Error Rate is an Index of Professional Attitude." Dissertation Abstracts International, 44(11): 3342-A, 1984.

15. Arnold, L. B. "Women's Education in the Nineteenth Century: Four Lives in Science." Dissertation Abstracts International, 44(12): 3650-A, 1984.

16. Arrick, E. K. "Persistence of Women and Men Science Majors at an Urban State University." Dissertation Abstracts International, 44(8): 2369-A, 1984.

17. Ault, C. R. et. al. "Constructing Vee Maps for Clinical Interviews on Molecular Concepts." Science Education, 68(4): 441-462, 1984.

18. Avons, S. E. "Microprocessors in Education Research Project." Final Report, United Kingdom; England, 1984. ED 244 814

19. Awodi, S. "A Comparative Study of Teaching Science (Biology) as Inquiry Versus Traditional Didactic Approach in Nigerian Secondary Schools." Dissertation Abstracts International, 45(6): 1707-A, 1984.

20. Azencot, M. and A. Blum. "Pupils', Students' and Teachers' Achievements in a Test on Field Experiments." Research in Science and Technological Education, 2(1): 47-53, 1984.

21. Baird, J. H., R. Lazarowtiz and V. Allman. "Science Choices and Preferences of Middle and Secondary School Students in Utah." Journal of Research in Science Teaching, 21(1): 47-54, 1984.

22. Baker, D. R. "Masculinity, Femininity and Androgeny Among Male and Female Science and Non-Science College Majors." School Science and Mathematics, 84(6): 459-467, 1984.

23. Barrow, L. H. "Elementary Science Education Library Resources in Graduate and Undergraduate Teacher Education Programs of New England." Paper presented at the Annual Meeting of the National Association for Research in Science Teaching, New Orleans, LA, April, 1984. ED 244 799

24. Barrow, L. H. and B. L. Bitner. "Cancer Education in High School Biology Textbooks." School Science and Mathematics, 84(4): 285-296, 1984.

25. Battista, M. T. and G. H. Krockover. "The Effects of Computer Use in Science and Mathematics Education Upon the Computer Literacy of Preservice Elementary Teachers." Journal of Research in Science Teaching, 21(1): 39-46, 1984.

26. Beall, D and H. Harty. "Inservice Teacher Reactions to Implementing Microcomputers in Elementary Science and Mathematic Classes." Journal of Computers in Mathematics and Science Teaching, 3(4): 34-38, 1984.

27. Benedetti, D. M. "The Effectiveness of an Instructional Adaption on the Acquisition of Science Information by Middle School Learning Disabled Students." Dissertation Abstracts International, 44(11): 3346-A, 1984.

28. Binkney, R. H. "A Study of the Relationship Between Achievement and Structure of Text in a High School Physics Classroom." Dissertation Abstracts International, 45(4): 994-A, 1984.

29. Bitner, B. L. "Impact Study of Energy Education Workshops on the Participants and Their Peer Teachers." Dissertation Abstracts International, 44(9): 2725-A, 1984.

30. Blosser, P. E. "What Research Says - Science Teacher Supply and Demand." School Science and Mathematics, 84(3): 244-249, 1984.

31. Blosser, P. E. "What Research Says: Achievement in Science." School Science and Mathematics, 84(6): 514-521, 1984.

32. Bonnstetter, R. J. "Teachers in Exemplary Programs: How Do They Compare?" Monograph based on the unpublished doctoral dissertation of Ronald J. Bonnstetter, "Characteristics of Teachers Associated with and Exemplary Program Compared with Science Teachers in General," University of Iowa, 1983. ED 244 791

33. Bottoms, C. L. "Investigations of Change in Attitude Toward Physics." Dissertation Abstracts International, 44(10): 3027-A, 1984.

34. Bradshaw, C. A. "The Relationship of Black Innercity Students' Perceptions of Ability to Expected and Assigned Grades in Science." Dissertation Abstracts International, 45(5): 1357-A, 1984.

35. Bredderman, T. "The Influence of Activity-Based Elementary Science Programs on Classroom Practices: A Quantitative Synthesis." Journal of Research in Science Teaching, 21(3): 289-303, 1984.

36. Brooks, J. A. S. "Secondary Laboratory Teachers' Student Grouping Decisions: A Descriptive Study." Dissertation Abstracts International, 44(9): 2663-A, 1984.

37. Brumby, M. N. "Misconceptions About the Concept of Natural Selection by Medical Biology Students." Science Education, 68(4): 493-503, 1984.

38. Burke, P. Y. "A Study to Determine the Trends in Attitude Toward Science Among Fourth, Fifth and Sixth Grade Male and Female Students." Dissertation Abstracts International, 44(9): 2663-A, 1984.

39. Burnett, J. D. "College Student Achievement in Chemistry With and Without Laboratory." Dissertation Abstracts International, 45(2): 394-A, 1984.

40. Cameron, R. K. K. "The Effects of Two Instructional Treatments on Eighth-Grade Students' Attitudes Toward Animal Life." Dissertation Abstracts International, 44(9): 2664-A, 1984.

41. Campbell, J. R. and C. Connolly. "Impact of Ethnicity on Math and Science Among the Gifted." Paper presented at the Annual Meeting of the American Education Research Association, New Orleans, LA, April 1984. ED 251 291

42. Carrick, T. "Some Biology Teachers' Goals for Advanced Level Teaching." Journal of Biological Education, 17(3): 205-214, 1983.

43. Carrick, T. "The Teaching of Options in JMB A-Level Biology: Some Teachers' Views. Journal of Biological Education, 17(4): 319-322, 1983.

44. Carter, C. "The Effects of Specific Learning Heuristics on the Conceptual Learning of Biology by Black High School Students." Dissertation Abstracts International, 44(9): 2726-A, 1984.

45. Cassels, J. R. T. and A. H. Johnstone. "The Effect of Language on Student Performance on Multiple Choice Tests in Chemistry." Journal of Chemical Education, 61(7): 613-615, 1984.

46. Chakagondua, J. G. "Defining Characteristics of a New Elementary Science Curriculum: Variance Among Developers, Teachers and Practices in Classrooms." Dissertation Abstracts International, 45(5): 1358-A, 1984.

47. Champagne, A. B. et. al. "A Perspective on the Differences Between Expert and Novice Performance in Solving Physics Problems." Paper presented at the meeting of the Australian Science Education Research Association, Sydney, Australia. ED 241 305

48. Chang, Y. "Effect of Inservice Training on Elementary Teachers' Attitudes Toward, Use of Techniques, and Resources for Inquiry-Discovery Science Teaching in Taiwan, Republic of China." Dissertation Abstracts International, 44(9): 2726-A, 1984.

49. Cho, H. and J. B. Kahle. "A Study of the Relationship Between Concept Emphasis in High School Biology Textbooks and Achievement Levels." Journal of Research in Science Teaching, 21(7): 725-733, 1984.

50. Churchman, D. "Issues Regarding Non Formal Evaluation on Non Formal Education in Zoos." Paper presented at the Biannual Meeting of the International Association of Zoo Educators, Edinburgh, Scotland, September, 1984. ED 250 172

51. Clevenstine, R. F. "An Analysis and Classification of the Performance Objectives of Thirty-Three Minicourses of the ISIS Program (Individualized Science Instructional System) and Their Achievement Tests Using Bloom's Cognitive Taxonomy of Educational Objectives." Dissertation Abstracts International, 45(2): 481-A, 1984.

52. Coffey, S. P. "A Comparison of the Effects of Three Remediation Strategies Within a Mastery Learning System in High School Chemistry. Dissertation Abstracts International, 44(10): 3027-A, 1984.

53. Cohen, H. G. "A Comparison of the Development of Spatial Conceptual Abilities of Students From Two Cultures." Paper Presented at the Annual Meeting of the National Association for Research in Science Teaching, New Orleans, LA, April, 1984. ED 244 806

54. Cohen, H. G. "The Effects of Two Teaching Strategies Utilizing Manipulatives on the Develpment of Logical Thought." Journal of Research in Science Teaching, 21(8): 769-778, 1984.

55. Collier, E. R. "The Effect of Student-Generated Analogies on Achievement in an Audio-Tutorial Botany Course." Dissertation Abstracts International, 44(9): 2726-A, 1984.

56. Collins, M. A. J. "Improving Learning With Computerized Tests." American Biology Teacher, 46(3): 188-191, 1984.

57. Conwell, C. L. R. "An Investigation of Changes in Elementary Teachers' Achievement in Science and Attitude Toward Teaching Science Due to Matching and Mismatching Science Activities With the Myers-Briggs Type Indicator. Dissertation Abstracts International, 44(9): 2726-A, 1984.

58. Cook, D. H. "The Development and the Evaluation of a Diagnostic Mathematics Pretest for Chemistry and of a Program to Strengthen Mathematics Proficiencies for Chemistry Students." Dissertation Abstracts International, 45(4): 1707-A, 1984.

59. Cortina, J. "A Delphi Study of the Perceived Reading Skill Needs of Community College Students as Determined by Community College Content Area Faculty." Dissertation Abstracts International, 44(8): 2423-A, 1984.

60. Costello, S. J. "Analysis of Errors Made by Students Solving Genetics Problems." Paper presented at the Annual Meeting of the National Association for Research in Science Teaching, New Orleans, LA, April, 1984. ED 244 783

61. Cothron, J. H. "The Formation of Ecological Concepts and Conceptual Systems by Upper Elementary Students." Dissertation Abstracts International, 44(12): 3651-A, 1984.

62. Crocker, R. K. "Determinants of Implementation of an Elementary Science Program." Journal of Research in Science Teaching, 21(2): 211-220, 1984.

63. DeBoer, G. E. "Factors Related to the Decision of Men and Women to Continue Taking Science Courses in College." Journal of Research in Science Teaching, 21(3): 325-329, 1984.

64. DeBoer, G. E. "A Study of Gender Effects in the Science and Mathematics Coursetaking Behavior of a Group of Students Who Graduated From College in the Late 1970's." Journal of Research in Science Teaching, 21(1): 95-103, 1984.

65. DeBoer, G. E. "Sense of Competence in Science as a Factor in the Career Decisions of Men and Women." Paper presented at the Annual Meeting of the National Association for Research in Science Teaching, New Orleans, LA, April, 1984. ED 243 716

66. Dechow, R. R. "A Comparison of Teams-Games-Tournaments (TGT) and Traditional Classroom Methods in High School Biology." Dissertation Abstracts International, 44(11): 3262-A, 1984.

67. De Hernandez, L., E. A. Marek and J. W. Renner. "Relationships Among Gender, Age and Intellectual Development." Journal of Research in Science Teaching, 21(4), 365-375, 1984.

68. Dertinger, T. D. "An Experimental Study of the Effects of Mastery Learning on the Locus of Control of Sixth Grade Science Students." Dissertation Abstracts International, 45(3): 737-A, 1984.

69. DeTure, L. R. and A. P. Miller. "The Effects of a Written Protocal Model on Teacher Acquisition of Extended Wait-Time." Paper presented at the Annual Meeting of the National Association for Research in Science Teaching, New Orleans, LA, 1984. ED 245 943

70. Devore, R. N. "Factors Related to Preservice Elementary School Teachers' Science Skills." Unpublished research report, Rutgers University, 1984. ED 247 112

71. Devore, R. N. "The Relationship of Cognitive Style, Cognitive Level, and Achievement in Science to the Development of Positive Attitudes Toward Science and Science Teaching." Dissertation Abstracts International, 45(2): 482-A, 1984.

72. Donaldson, H. C. "A Study of the Laboratory Science Teaching Skills of Elementary Teachers." Doctoral Dissertation, Kansas State University, Kansas, 1984. SE 044 868

73. Doran, R. L. and W. J. Jacobson. "What Research Says: How Are Our Fifth Graders Doing?" Science and Children, 22(1): 41-42, 1984.

74. Dunkelberger, G. E. and H. Heikkinen. "The Influence of Repeatable Testing on Retention in Mastery Learning." School Science and Mathematics, 84(7): 590-597, 1984.

75. Durr, B. P. "Analysis of Chemistry Curricula for Cognitive Level of Demand." Dissertation Abstracts International, 44(11): 3342-A, 1984.

76. Duschl, R. A. "Science Teachers' Beliefs About the Nature of Science and the Selection, Implementation, and Development of Instructional Tasks: A Case Study." Dissertation Abstracts International, 45(2): 482-A, 1984.

77. Dyer, E. A. "A Description of Science Education Inservice Program Characteristics of Science Teachers, Grades 7-12, in the Panhandle of Texas." Dissertation Abstracts International, 45(1), 68-A, 1984.

78. Ehindero, O. J. "The Acquisition and Transfer of Transitive Inference by Some Nigerian Children Aged 4 to 7 Years." Science Education, 68(4): 427-440, 1984.

79. El-Rashed, I. M. "Influence of Teacher Wait-Time and Question Level on Eighth Grade Students' Science Achievement and Attitudes Toward Science in Saudi Arabia." Dissertation Abstracts International, 45(5): 1358-A, 1984.

80. Erb, T. O. and W. S. Smith. "Validation of the Attitude Toward Women in Science Scale for Early Adolescents." Journal of Research in Science Teaching, 21(4): 391-397, 1984.

81. Erickson, G. L. and L. J. Erickson. "Females and Science Achievement: Evidence, Explanations, and Implications." Science Education, 68(2): 63-89, 1984.

82. Ertwine, D. R. "The Thayer Concept Versus Traditional Lecture Instruction: A Comparison of Two Teaching Methods at the United States Military Academy." Dissertation Abstracts International, 44(9): 2729-A, 1984.

83. Falkowski, H. W. "A Study of the Relationship Between Readability of a Chemistry Textbook and Performance in First Year College Chemistry." Dissertation Abstracts International, 44(7): 2026-A, 1984.

84. Farnsworth, C. H. and V. J. Mayer. "An Assessment of the Validity and Discrimination of the Intensive Time-Series Design by Monitoring Learning Differences Between Students with Different Cognitive Tendencies." Journal of Research in Science Teaching, 21(4): 345-355, 1984.

85. Fields, L. "Evaluation of a University Biology Course Designed to Promote Development of Logical Reasoning Skills in Educationally Disadvantaged Minority Students Planning Careers in Health Care Professions." Dissertation Abstracts International, 45(1): 93-A, 1984.

86. Finley, F. N. "Using Propositions from Clinical Interviews as Variables to Compare Student Knowledge." Journal of Research in Science Teaching, 21(8): 809-818, 1984.

87. Firstman, A. "Time Management and Laboratory Scheduling at a Community College: Governance and Management." Ed.D. Practicum, Nova University, 1984. ED 247 094

88. Flexer, B. K. and M. Borun. "The Impact of a Class Visit to a Participatory Science Museum Exhibit and a Classroom Science Lesson." Journal of Research in Science Teaching, 21(9): 863-873, 1984.

89. Fraser-Abder, P. "The Effect of Participation in an Activity Oriented Science Curriculum Development Workshop on the Attitude of Elementary teachers in Trinidad and Tobago." Paper presented at the Annual Meeting of the National Association for Research in Science Teaching, New Orleans, LA, April, 1984. ED 244 779

90. Freeman, W. A. "Relative Long-Term Benefits of a PSI and a Traditional-Style Remedial Chemistry Course." Journal of Chemical Education, 61(7): 617-619, 1984.

91. Friedler, Y. and P. Tamir. "Triangulation Approach to Research on Science Learning in the School Laboratory." Paper presented at the Annual Meeting of the National Association for Research in Science Teaching, New Orleans, LA, April, 1984. ED 245 910

92. Gabel, D. and R. D. Sherwood. "Analyzing Difficulties With Mole-Concept Tasks by Using Familiar Analog Tasks." Journal of Research in Science Teaching, 21(8): 843-851, 1984.

93. Gabel, D. L., R. D. Sherwood and L. Enochs. "Problem-Solving Skills of High School Chemistry Students." Journal of Research in Science Teaching, 21(2): 221-233, 1984.

94. Gan, S. L. "Study Behavior and Achievement in Science of Form Five Pupils in Two Secondary Schools in Kuala Lumpur." Journal of Science and Mathematics Education in Southeast Asia, 7(1): 20-25, 1984.

95. Gardner, K. L. "The Evolution Controversy in the Educational Literature From 1900-1981 Discussed in Terms of Kuhn's Structure of Scientific Revolutions." Dissertation Abstracts International, 45(4): 1089-A, 1984.

96. Garnett, P. J. and K. Tobin. "Reasoning Patterns of Preservice Elementary and Middle School Science Teachers." Science Education, 68(5): 621-631, 1984.

97. Garrad, L. K. L. "The Effectiveness of the Developmental Project Method of Producing Science Curriculum Materials." Dissertation Abstracts International, 44(8): 2426-A, 1984.

98. Gayford, C. G. "Water Relations and the Vacuolated Plant Cell: A Brief Study of the Topic at Advanced Level in School Biology." Journal of Biological Education, 18(2): 151-155, 1984.

99. Gerace, W. J. and J. P. Mestre. "Identifying Learning Handicaps of College Age Spanish-Speaking Bilingual Students Majoring in Technical Subjects." Bilingual Research Project Report, Massachusetts University, Amherst, 1984. ED 241 278

100. Goldberg, F. M. and J. C. Shuman. "Using Guided Design to Help Students Learn About the Energy Problem." Journal of College Science Teaching, 14(2): 122-127, 1984.

101. Good, R. "Scientific Problem Solving by Expert Systems." Journal of Research in Science Teaching, 21(3): 331-340, 1984.

102. Gorman, M. E. "The Effect of Disconfirmatory Instructions on Scientific Problem-Solving." Paper presented at the Annual Meeting of the Eastern Psychological Association, Baltimore, MD, April, 1984. ED 244 785

103. Greenbowe, T. J. "An Investigation of Variables Involved in Chemistry Problem Solving." Dissertation Abstracts International, 44(12): 2651-A, 1984.

104. Gussett, J. H. "Relationships Between Selected Reading Performance Objectives and Science Achievement in a Middle School." Dissertation Abstracts International, 45(3): 810-A, 1984.

105. Hackling, M. W. and D. Treagust. "Research Data Necessary for Meaningful Review of Grade Ten High School Genetics Curricula." Journal of Research in Science Teaching, 21(2): 197-209, 1984.

106. Hafez, A. I. "The Relationship Between the Cerebral Lateralization for Arabic Language and Achievement in Science." Dissertation Abstracts International, 44(8): 2429-A, 1984.

107. Hale, M. E. "Development of a Computer Animated Science Process Skills Test." Paper presented at the Annual Meeting of the National Association for Research in Science Teaching, New Orleans, LA, April, 1984. ED 248 111

108. Hall, G. E. et. al. "Making Change Happen: A Case Study of School District Implementation." Paper presented at the Annual Meeting of the American Educational Research Association, Boston, MA, April, 1980. ED 250 162

109. Handley, H. M. and L. W. Morse. "Two-Year Study Relating Adolescents' Self-Concept and Gender Role Perceptions to Achievement and Attitudes Toward Science." Journal of Research in Science Teaching, 21(6): 599-607, 1984.

110. Harlen, W. "Science in Schools, Agell: Report No. 2." Department of Education and Science, London (England). SE045162.

111. Harty, H., Anderson and Enveles. "Exploring Relationships Among Elementary School Students' Interest in Science, Attitudes Toward Science, and Reactive Curiosity." School Science and Mathematics, 84(4): 308-315, 1984.

112. Harty, H. and D. Beall. "Toward the Development of a Children's Science Curiosity Measure." Journal of Research in Science Teaching, 21(4): 425-536, 1984.

113. Harty, H. and D. Beall. "Attitudes Toward Science of Gifted and Nongifted Fifth Graders." Journal of Research in Science Teaching, 21(5): 483-488, 1984.

114. Harvey, D. "An Investigation of the Effectiveness of a Teaching Machine in Improving the Formal Reasoning Ability of Students Engaged in the Study of Chemistry at a Community College." Dissertation Abstracts International, 45(1): 142-A, 1984.

115. Harvey, T. J. and M. Wareham. "An Investigation into Sex Differences in Certain Aspects of Science Practical Work with First-Year Secondary School Pupils in Single Sex and Mixed Teaching Groups." Research in Science and Technological Education, 2(2): 187-195, 1984.

116. Haury, D. L. "The Contribution of Science Locus of Control Orientation to Expressions of Attitude Toward Science Teaching." Paper presented at the Annual Meeting of the National Association for Research in Science Teaching, New Orleans, LA, April, 1984. ED 244 829

117. Hayes, R. W. "The Relationship of Student Attitude to Academic Achievement in Reading/Language, Mathematics Science, and Social Studies When Gender, Grade Level and Class Size are Controlled." Dissertation Abstracts International, 45(1): 125-A, 1984.

118. Heller, J. I. and H. N. Hungate. "Theory-Based Instruction in Description of Mechanics Problems." Paper presented at the Annual Meeting of the American Education Research Association, New Orleans, LA, April, 1984. ED 249 043

119. Helseth, E. A. "The Relationships Among Process Skills Instruction, Achievement, Formal Operational Thinking Ability, Integrated Science Process Skills Ability, Academic Aptitude, Perceived Locus of Control, and Achievement Motivation for Nonscience Majors Enrolled in a College Biology Course." Dissertation Abstracts International, 45(2): 482-A, 1984.

120. Hertz-Lazarowitz, R., et. al. "Student-Student Interactions in Science Classrooms: A Naturalistic Study." Science Education, 68(5): 603-619, 1984.

121. Hickman, F. M. "Education in Science and Health: An Emerging Synthesis." Dissertation Abstracts International, 44(9): 2743-A, 1984.

122. Hirsch, C. R. "A Profile of Michigan Teachers of High School Biology, Chemistry, and Physics: 1980-1983." Science Education, 68(5): 579-587, 1984.

123. Hodgson, B. K. and P. J. Murphy. "A CAL-Based Distance Education Project in Evolution: 2. Evaluation of the CAL-Based Project in Relation to Alternative Projects." Journal of Biological Education, 18(2): 141-146, 1984.

124. Hodson, D. "Some Effects of Changes in Question Structure and Sequence on Performance in a Multiple Choice Chemistry Test." Research in Science and Technological Education, 2(2): 177-185, 1984.

125. Hodson, D. "The Effect of Changes in Item Sequence on Student Performance in a Multiple-Choice Chemistry Test." Journal of Research in Science Teaching, 21(5): 489-495, 1984.

126. Hofstein, A. and W. W. Welch. "The Stability of Attitudes Towards Science Between Junior and Senior High School." Research in Science and Technological Education, 2(2): 131-138, 1984.

127. Holden, C. C. and L. H. Barrow. "Validation of the Test of Energy Concepts and Values for High School." Journal of Research in Science Teaching, 21(2): 187-196, 1984.

128. Holliday, W. G., H. G. Wittaker and K. D. Loose. "Differential Effects of Verbal Aptitude and Study Questions on Comprehension of Science Concepts." Journal of Research in Science Teaching, 21(2): 143-150, 1984.

129. Hsu, R. "Construction and Validation of a Pictorial (Graphic) Physics Test and Analysis of Its Relationship to Intellectual Development and Science Aptitude for Junior High School Students in Taiwan." Dissertation Abstracts International, 44(8): 2429-A, 1984.

130. Iker, S. "Science, Children, and Television." Mosaic, 14(6): 8-13, 1983.

131. Ilogu, G. C. "Construction and Validation of Instrument to Measure Introductory Chemistry Cognitive Laboratory Skills." Dissertation Abstracts International, 44(10): 3027-A, 1984.

132. Ingle, R. B. "Nuffield Chemistry in Britain 1961-1982. Part II. Evaluation and Revision of O-Level Publications." Science Education, 68(5): 541-561, 1984.

133. Isaacs, P. A. "Development of a Test of Process Skills for Grade 3 Elementary School Pupils." Paper presented at the Annual Meeting of the National Association for Research in Science Teaching, New Orleans, LA, April, 1984. ED 247 093

134. Isom, F. S. "The Effect of a Prelaboratory Preparation Period on the Academic Performance of Students Taking 103 Chemistry at Auburn University. Dissertation Abstracts International, 44(11): 3342-A, 1984.

135. Ivowi, U. M. O. "Misconceptions in Physics Amongst Nigerian Secondary School Students." Physics Education, 19(6): 279-285, 1984.

136. Iyiola, A. O. and W. J. Wilkinson. "A Study of the Biological Science Curriculum for Secondary Schools in Nigeria." Research in Science and Technological Education, 2(2): 139-152, 1984.

137. Johns, K. W. "Wanted: Money and Time for Science." School Science and Mathematics, 84(4): 271-276, 1984.

138. Jolly, P. E. and B. M. Strawitz. "Teacher-Student Cognitive Style and Achievement in Biology." Science Education, 68(4): 487-492, 1984.

139. Kappraff, R. M. "Enriching the Science Curriculum with Creative Hypothesis Formation." Dissertation Abstracts International, 45(2): 485-A, 1984.

140. Kelly, A. et. al. "Girls Into Science and Technology. Final Report." United Kingdom; England. ED 250 203

141. Kermis, W. J. "TCIQ: An Identification by Intensity and Frequency of "Potent" Testing Cues in Science." Journal of Research in Science Teaching, 21(6): 609-621, 1984.

142. Kern, E. L. and J. R. Carpenter. "Enhancement of Student Values, Interests and Attitudes in Earth Science Through a Field-Oriented Approach." Journal of Geological Education, 32(5): 299-305, 1984.

143. Kinsey, T. G. and J. H. Wheatley. "The Effects of an Environmental Studies Course on the Defensibility of Environmental Attitudes." Journal of Research in Science Teaching, 21(7): 675-683, 1984.

144. Koballa, T. R. "A Validation Process for Designing One-Sided and Two-Sided Communications to Use in Persuading Teachers of the Need to Teach Energy Conservation to Children." Science Education, 68(2): 91-103, 1984.

145. Koballa, T. R. "Changing Attitudes Toward Energy Conservation: The Effect of Development Advancement on the Salience of One-Sided and Two-Sided Persuasive Communications." Journal of Research in Science Teaching, 21(6): 659-668, 1984.

146. Koballa, T. R. "Designing a Likert-Type Scale to Assess Attitudes Toward Energy Conservation: A Nine-Step Process." Journal of Research in Science Teaching, 21(7): 709-723, 1984.

147. Koran, M. L. and J. J. Koran. "Aptitude-Treatment Interaction Research in Science Education." Journal of Research in Science Teaching, 21(8): 793-808, 1984.

148. Koran, J. J. et. al. "Attention and Curiosity in Museums." Journal of Research in Science Teaching, 21(4): 357-363, 1984.

149. Krieger, J. H. "Study Indicated Some Improvements in U.S. Science Education." Chemical and Engineering News, 62(24): 26-28, 1984.

150. Laing, D. N. "Graphic Representation of Selected Anatomical Concepts." Dissertation Abstracts International, 44(7): 2084-A, 1984.

151. Lane, C. L. "A Study of Science Teachers' Perceptions of the Relevancy and Implementation of the Science Curriculum Policy for Grades Seven, eight, and Nine in the Metropolitan Nashville-Davidson County Public Schools of Tennessee." Dissertation Abstracts International, 45(3): 708-A, 1984.

152. Larkin, J. H. and B. Rainard. "A Research Methodology for Studying How People Think." Journal of Research in Science Teaching, 21(3): 235-254, 1984.

153. Lashier, W. S. and W. Y. Ryoo. "A Longitudinal Study of the Supply and Demand for Physics and Chemistry Teachers in Kansas." Journal of Research in Science Teaching, 21(1): 17-26, 1984.

154. Lawrenz, F. P. "An Evaluation of the Effect of Two Different Lengths of Inservice Training on Teacher Attitudes." Journal of Research in Science Teaching, 21(5): 497-506, 1984.

155. Lawrenz, F. and T. W. Munch. "The Effect of Grouping of Laboratory Students on Selected Educational Outcomes." Journal of Research in Science Teaching, 21(7): 699-708, 1984.

156. Lawson, A. E. and Bealer, J. M. "The Acquisition of Basic Quantitative Reasoning Skills During Adolescence: Learning or Development." Journal of Research in Science Teaching, 21(4): 417-423, 1984.

157. Lawson, A. E. and J. M. Bealer. "Cultural Diversity and Differences in Formal Reasoning Ability." Journal of Research in Science Teaching, 21(7): 735-743, 1984.

158. Lawson, A. E., D. I. Lawson and C. A. Lawson. "Proportional Reasoning and the Linguistic Abilities Required for Hypothetico-Deductive Reasoning." Journal of Research in Science Teaching, 21(2): 119-131, 1984.

159. Lawson, R. A. "Student Understanding of Single Particle Dynamics." Dissertation Abstracts International, 45(5): 1358-A, 1984.

160. Lederman, N. G. "Delineating Classroom Variables Related to Students' Conceptions of the Nature of Science." Dissertation Abstracts International, 45(2): 483-A, 1984.

161. Lederman, N. G. "Delineating Classroom Variables Related to Students' Conceptions of the Nature of Science." Paper presented at the Annual Meeting of the National Association for Research in Science Teaching, New Orleans, LA, April, 1984. ED 243 699

162. Lee, M. J. "An Analysis of Attitudes Concerning Science and Formal Reasoning Ability Among Senior High School Students in Taiwan." Dissertation Abstracts International, 44(11): 3342-A, 1984.

163. Lehman, J. R., J. J. Koran and M. L. Koran. "Interaction of Learner Characteristics with Learning from Three Models of the Periodic Table." Journal of Research in Science Teaching, 21(9): 885-893, 1984.

164. Lehman, J. R. and K. M. Lehman. "The Relative Effects of Experimenter and Subject Generated Questions on Learning from Museum Case Exhibits." Journal of Research in Science Teaching, 21(9): 931-935, 1984.

165. Leonard, W. H. "An Experimental Test of an Extended Discretion Laboratory Approach for University General Biology." Paper presented at the Annual Meeting of the National Association for Research in Science Teaching, New Orleans, LA, April, 1984. ED 245 929

166. Leonard, W. H. and L. F. Lowery. "The Effects of Question Types in Textual Reading Upon Retention of Biology Concepts." Journal of Research in Science Teaching, 21(4): 377-384, 1984.

167. Levin, J. and H. S. Fowler. "Sex, Grade and Course Differences in Attitudes that are Related to Cognitive Performance in Secondary Science." Journal of Research in Science Teaching, 21(2): 151-166, 1984.

168. Lips, H. M. "Math/Science Self-Schemas and Curriculum Choices Among University Women." Paper presented at the American Psychological Association, Toronto, Canada, August, 1984. ED 250 194

169. Little, L. F. The Influence of Structured Programming Gender, Cognitive Development and Engagement on the Computer Programming Achievement and Logical Thinking Skills of Secondary Students." Dissertation Abstracts International, 45(6): 1708-A, 1984.

170. Lloyd, C. V. "The Effects of a Priming Activity on the Reading Comprehension of a Science Passage of Low Prior Knowledge Subjects." Dissertation Abstracts International, 45(4): 1082-A, 1984.

171. Lombana, J. D. "A Study of the Combination of a Preordinate and Emergent Design to Evaluate the Implementation of an Innovative Science Program." Dissertation Abstracts International, 45(1): 157-A, 1984.

172. London, E. D. "Comparisons of Attitudes Toward Science and Science Teaching Among Students Enrolled in Elementary Teacher Education Programs and Selected Elementary Teachers." Dissertation Abstracts International, 44(8): 2429-A, 1984.

173. Lord, T. R. "The Effects of Visual-Spatial Aptitude on the Study of College Biology." Dissertation Abstracts International, 44(8): 2430-A, 1984.

174. Loucks, S. F. "Concerns Expressed by Elementary School Teachers About the Implementation of the SCIS Curriculum." Paper presented at the Annual Meeting of the Association for the Education of Teachers of Science, Cincinnati, OH, March, 1977. ED 290 163

175. Maiman, S. I. "Assessment of Piagetian Cognitive Abilities Required for the Twelfth Grade Male Science Students in Saudi Arabia to Understand Selected Chemistry Concepts Taught to Them." Dissertation Abstracts International, 44(11): 3343-A, 1984.

176. Malone, M. R. "Concerns Based Adoption Model (CBAM): Basis for an Elementary Science Methods Course." Journal of Research in Science Teaching, 21(7): 755-768, 1984.

177. Matyas, M. L. "Science Career Interests, Attitudes, Abilities, and Anxiety Among Secondary School Students: The Effects of Gender, Race/Ethnicity, and School Type/Location." Paper presented at the Annual Meeting of the National Association for Research in Science Teaching, New Orleans, LA, April, 1984. ED 251 309

178. McCarley, J. W. "The Status of Energy Education at the Secondary School Level in the State of Alabama." Dissertation Abstracts International, 44(7): 2107-A, 1984.

179. McFarlane, P. J. "A Study of the Effect of Teaching-Learning Units and Consultant Services on the Attitude of Second and Third Grade Teachers Toward Science and the Teaching of Science." Dissertation Abstracts International, 44(7): 2107-A, 1984.

180. McGarity, J. R. and D. P. Butts. "The Relationship Among Teacher Classroom Management Behavior, Student Engagement, and Student Achievement of Middle and High School Science Students of Varying Aptitude." Journal of Research in Science Teaching, 21(1): 55-61, 1984.

181. McGeever, J. M. "State and Local Initiatives to Alleviate Teacher Shortages in Mathematics and Science." AEL Occasional Paper 014. Charleston, WV, 1984. ED 251 318

182. McGuire, B. L. and W. G. Holliday. "Carry-Over Effects of Focusing Postquestions Adjunct to Computer-Animated Graphics." Paper presented at the Annual Meeting of the American Educational Research Association, New Orleans, LA, April, 1984. ED 247 131

183. McIntosh, W. J. "The Effects of Augmenting the Learning of Physical Science Rules by Imaging Prototypic Examples of Subordinate Concepts." Dissertation Abstracts International, 45(3): 800-A, 1984.

184. McKenzie, D. L. "Effects of Laboratory Activities and Simulations on the Engagement and Acquisition of Graphing Skills by Eighth Grade Students with Varying Levels of Spatial Scanning Ability and Cognitive Development." Dissertation Abstracts International, 44(8): 2430-A, 1984.

185. McKinnon, G. R. "The Relationship of Elementary Teacher's Space Relations Perceptual Ability and Their Attitude Toward Science and Science Teaching." Dissertation Abstracts International, 45(5): 1359-A, 1984.

186. Meinhard-Pellens, R. K. "Study of a National Science Education Exemplar." Dissertation Abstracts International, 44(8): 2430-A, 1984.

187. Mercurio, J. et. al. "Performance of Project Advance Students on the AP Biology Examination." American Biology Teacher, 46(2): 106, 08, 1984.

188. Metcalfe, R. J. et. al. "Teaching Science Through Drama: An Empirical Investigation." Research in Science and Technological Education, 2(1): 77-81, 1984.

189. Mika, J. G. "The Effectiveness of a Game Advance Organizer When Used by Concrete and Formal Operational Students Learning to Solve Mendelian Genetics Problems." Dissertation Abstracts International, 45(4): 1026-A, 1984.

190. Mims, R. L. "Utilization of Instructional Media and Techniques in Physical Geology Courses of the Two-Year Colleges of Texas and Selected Colleges of Other States." Dissertation Abstracts International, 44(11): 3252-A, 1984.

191. Mintzes, J. J. "Naive Theories in Biology: Children's Concepts of the Human Body." School Science and Mathematics, 84(7): 548-555, 1984.

192. Mintzes, J. J. and M. W. Arnaudin. "Children's Biology: A Review of Research on Conceptual Development in the Life Science, Report." North Carolina University, Department of Biological Sciences, Wilmington, NC, 1984. ED 249 044

193. Mitman, A. L. and S. Y. Osaki. "Life Science Instruction and its Relationship to Scientific Literacy at the Intermediate Level." Paper presented at the Annual Meeting of the National Association for Reserach in Science Teaching, New Orleans, LA, April, 1984. ED 250 148

194. Monk, J. S. "An Examination of Methods Used to Generate Daily Group Scores from Single-Item-Series Designs." Journal of Research in Science Teaching, 21(3): 315-324, 1984.

195. Monk, J. S. "Using an Intensive Time-Series Design to Examine Daily Achievement and Attitude of Eighth- and Ninth-grade Earth Science Students Grouped by Cognitive Tendency, Sex, and IQ." Dissertation Abstracts International, 44(9): 2727-A, 1984.

196. Moore, D. E. "The Effects of Guided Experiences with Animals on the Beliefs, Attitudes, Behavioral Intentions and Knowledge of Children." Dissertation Abstracts International, 44(9): 2727-A, 1984.

197. Morgenstern, C. F. and J. W. Renner. "Measuring Thinking with Standardized Science Tests." Journal of Research in Science Teaching, 21(6): 639-648, 1984.

198. Morrisey, J. T. and L. Barrow. "A Review of Energy Education: 1975 to NEED 1981." Science Education, 68(4): 365-379, 1984.

199. Mulder, T. and A. H. Verdonk. "A Behavioral Analysis of the Laboratory Learning Process: Redesigning a Teaching Unit on Recrystallization." Journal of Chemical Education, 61(5): 451-453, 1984.

200. Munby, H. "A Qualitative Approach to the Study of a Teacher's Beliefs." Journal of Research in Science Teaching, 21(1): 27-38, 1984.

201. National Association of Biology Teachers. "Factors Affecting the Retention of Girls in Science Courses and Careers: Case Studies of Selected Secondary Schools." A Study Conducted for the NSB Commission on Pre-College Education in Mathematics, Science, and Technology, Washington, DC, 1984. ED 244 781

202. Nichter, R. "International Science Education: A Study of UNESCO Science Education Improvement Projects in Selected Angolophone Countries of Africa: Project Problems." Science Education, 68(4): 381-396, 1984.

203. Ogunniyi, M. B. "An Investigation of the Nature of Verbal Behaviors in Science Lessons." Science Education, 68(5): 595-396, 1984.

204. Okebukola, P. A. and M. B. Ogunniyi. "Cooperative, Competitive, and Individualistic Science Laboratory Interactions Patterns-Effects on Students' Achievement and Acquisition of Practical Skills." Journal of Research in Science Teaching, 21(9): 875-884, 1984.

205. Oldham, V. and W. Brouwer. "Mendelian Genetics: Paradigm, Conjecture, or Research Program." Journal of Research in Science Teaching, 21(6): 623-637, 1984.

206. Oliver, J. S. and N. D. Anderson. "Science Teaching as a Career Choice of Eighth Grade Students." Paper presented at the Annual Meeting of the National Association for Research in Science Teaching, New Orleans, LA, April, 1984. ED 247 124

207. Olstad, R. G. and J. L. Beal. "The Science and Mathematics Teacher Shortage: A Study of Recent Graduates." Science Education, 68(4): 397-402, 1984.

208. Onawola, R. S. T. "The Information Processed in Non-Verbal and Science-Related Verbal Problems by Selected Groups of Nigerian and American College Students." Dissertation Abstracts International, 45(6): 1694-A, 1984.

209. Orlich, D. C. "Inservice Education: A Problem or a Solution?" Science and Children, 21(5): 33-35, 1984.

210. Padilla, M. J. and J. R. Okey. "The Effects of Instruction on Integrated Science Process Skill Achievement." Journal of Research in Science Teaching, 21(3): 277-287, 1984.

211. Pallrand, G. J. and F. Seeber. "Spatial Ability and Achievement in Introductory Physics." Journal of Research in Science Teaching, 21(5): 507-516, 1984.

212. Papenfus, J. N. "The Selection of Curriculum Content for Biology in the Senior Secondary School Phase." Dissertation Abstracts International, 44(8): 2345-A, 1984.

213. Peabody, M. B. "The Effect of Concrete Examples on Transitional and Formal Students in the Instruction of Chemical Bonding." Dissertation Abstracts International, 45(4): 1088-A, 1984.

214. Peard, T. L. "A Study of Student Understanding of Mendelian Genetics, Using Microcomputers, Concept Maps, and Clinical Interviews as Analytical Tools." Dissertation Abstracts International, 44(11): 3343-A, 1984.

215. Peretz, M. B. and P. Tamir. "What do Curriculum Developers Do?" Paper presented at the Annual Meeting of the American Educational Research Association, New Orleans, LA, 1984. ED 244 788

216. Perry, B. E. "The Acquisition of Notions of Qualitative Speed: Analysis of Piaget's Concepts of Movement and Speed Using Ordering Analysis." Dissertation Abstracts International, 44(7): 2268-A, 1984.

217. Pestel, B. C. "Freshman Chemistry Programs: Assessment and Recommendations." Dissertation Abstracts International, 44(9): 2729-B, 1984.

218. Pfeiffenberger, W. and G. F. Wheeler. "A Curriculum Survey of High School Physics Courses." Physics Teacher, 22(9): 569-575, 1984.

219. Plumlee, D. S. "Determination and Validation of Learning Hierarchies in Two-Year College Chemistry." Dissertation Abstracts International, 44(11): 3272-A, 1984.

220. Poduska, E. L. "The Performance of College Students on Piaget-Type Tasks Related to Speed." Dissertation Abstracts International, 44(12): 3651-A, 1984.

221. Psillos, D. K. et. al. "The Self-Esteem of Pre-Service Physics Education Students." Research in Science and Technological Education, 2(2): 127-130, 1984.

222. Raines, S. J. "Problem-Similarity Recognition and Problem-Solving Success in High School Chemistry." Dissertation Abstracts International, 45(3): 800-A, 1984.

223. Raizada, K. S. Pedagogic Consensuality, Consensibility, and Commensurability in Chemistry Teaching. Mather's Thesis, University of Calgary, Alberta, Canada, 1983. ED 247 092

224. Rakow, S. J. "What Research Says: What's Happening in Elementary Science: A National Assessment." Science and Children, 22(2): 39-40, 1984.

225. Rakow, S. J. "Predictors of Science Inquiry Knowledge." Paper presented at the Annual Meeting of the National Association for Research in Science Teaching, New Orleans, LA, April, 1984. ED 248 131

226. Rakow, S. J., Welch and Hueftle. "Student Achievement in Science: A Comparison of National Assessment Results." Science Education, 68(5): 571-578, 1984.

227. Randolph, C. F. "The Relationships Among Cognitive Style, Achievement in Science, Selected Personality Variables, and the Sex of Students." Dissertation Abstracts International, 44(9): 2728-A, 1984.

228. Reese, W. F. "Method Study: Seven Years Later." Science and Children, 22(1): 40, 1984.

229. Reid, D. "Readability and Science Worksheets in Secondary Schools." Research in Science and Technological Education, 2(2): 153-165, 1984.

230. Reif, R. J. "The Development of Formal Reasoning Patterns Among University Science and Mathematics Students." Dissertation Abstracts International, 45(3): 766-A, 1984.

231. Reisner, E. R. "Projections of Future Shortages of Mathematics and Science Teachers." Paper presented at the Annual Meeting of the American Educational Research Association, New Orleans, LA, April, 1984. ED 243 703

232. Renner, J. W. "Student Opinions of the Laboratory Activities in the Learning Cycle in Secondary School Physics." Paper presented at the Annaul Meeting of the National Association for Research in Science Teaching, New Orleans, LA, April, 1984. ED 244 798

233. Renner, J. W. et. al. Sequencing Language and Activities in Teaching High School Physics - A Report to the National Science Foundation. University of Oklahoma, 1983. ED 238 732

234. Rhoton, J. "A Study of Science Education in Tennessee as Perceived by Science Teachers and Principals." Dissertation Abstracts International, 45(2): 403-A, 1984.

235. Rideng, I. M. and R. Schibeci. "The Development and Validation of a Test of Biology-Related Attitudes." Research in Science and Technological Education, 2(1): 21-29, 1984.

236. Riggs, P. A. "The Effect of the Introductory Animal Science Laboratory Manual on Student Achievement." Dissertation Abstracts International, 44(8): 2431-A, 1984.

237. Rivero, R. E. "The Immediate Achievement and Retention of Botany Content in a Natural Science Course Taught by Audio-Tutorial and Conventional Laboratory Methods." Dissertation Abstracts International, 45(6): 1708-A, 1984.

238. Ronning, R. R., D. McCurdy and R. Ballinger. "Individual Differences: A Third Component in Problem-Solving Instruction." Journal of Research in Science Teaching, 21(1): 71-82, 1984.

239. Rosenthal, D. B. "Social Issues in High School Biology Textbooks: 1963-1983." Journal of Research in Science Teaching, 21(8): 819-831, 1984.

240. Rowe, M. B. "What Research Says: Meeting Science Education Goals With 3-2-1 Contact." Science and Children, 21(7): 38-39, 1984.

241. Rowell, J. A. and C. J. Dawson. "Controlling Variables: Testing a Programme for Teaching a General Solution Strategy." Research in Science and Technological Education, 2(1): 37-46, 1983.

242. Russell, A. T. "The Use of Media by Freshman Chemistry Students." Dissertation Abstracts International, 45(3): 766-A, 1984.

243. Saegert, M. C. M. "The Effects on Science Pupils' Achievement and Attitude of Providing Information to Secondary Science Student Teachers About Pupils' and Teachers' Learning Styles." Dissertation Abstracts International, 44(11): 3343-A, 1984.

244. Sanford, J. P. "Management and Organization in Science Classrooms." Journal of Research in Science Teaching, 21(6): 575-587, 1984.

245. Saunders, W. L. and D. Shepardson. "A Comparison of Concrete and Formal Science Instruction Upon Science Achievement and Reasoning Ability of Sixth Grade Students." Paper presented at the Annual Meeting of the National Association for Research in Science Teaching, New Orleans, LA, April, 1984. ED 244 797

246. Seddon, G. M. and K. E. Shubber. "The Effects of Presentation Mode and Colour in Teaching the Visualisation of Rotation in Diagrams of Molecular Structures." Research in Science and Technological Education, 2(2): 167-176, 1984.

247. Self, C. C. et. al. "Computers in Audio-Tutorial Biology." American Biology Teacher, 46(3): 168-172, 1984.

248. Severeide, R. C. and E. L. Pizzini. "What Research Says: The Role of Play in Science." Science and Children, 21(8): 58-61, 1984.

249. Sherris, J. D. and J. B. Kahle. "The Effects of Instructional Organization and Locus of Control Orientation on Meaningful Learning in High School Biology Students." Journal of Research in Science Teaching, 21(1): 83-94, 1984.

250. Shrigley, R. L. and T. R. Koballa. "Attitude Measurement: Judging the Emotional Intensity of Likert-Type Science Attitude Statements." Journal of Research in Science Teaching, 21(2): 11-118, 1984.

251. Shymansky, J. "BSCS Programs: Just How Effective Were They?" American Biology Teacher, 46(1): 54-57, 1984.

252. Sirota, L. H. "Biochemistry for Nutrition/Dietetics Students: Course Content." Journal of Chemical Education, 61(5): 430-433, 1984.

253. Skoog, G. "The Coverage of Evolution in High School Biology Textbooks Pubolished in the 1980's." Science Education, 68(2): 117-128, 1984.

254. Smith, E. L. and C. W. Anderson. "Plants as Producers: A Case Study of Elementary Science Teaching." Journal of Research in Science Teaching, 21(7): 685-698, 1984.

255. Smith, E. L. and C. W. Anderson. The Planning and Teaching Intermediate Science Study: Final Report. Research Series No. 147. Michigan State University, East Lansing, 1984. ED 250 161

256. Smith, M. U. and R. Good. "Problem Solving and Classical Genetics: Successful Versus Unsuccessful Performance." Journal of Research in Science Teaching, 21(9): 895-912, 1984.

257. Smith, S. H. "The Effect of Sex, Achievement, and Science Self-Concept on Science Career Preferences of Young Urban Black Students." Dissertation Abstracts International, 45(3): 800-A, 1984.

258. Smith, R. F. "The Investigation of Role Models and Women's Choices of Science-Related Careers." Dissertation Abstracts International, 44(11): 3343-A, 1984.

259. Smail, B. and A. Kelly. "Sex Differences in Science and Technology Among 11-Year-Old School Children: I - Cognitive." Research in Science and Technological Education, 2(1): 61-76, 1984.

260. Smail, B. and A. Kelly. "Sex Differences in Science and Technology Among 11-Year-Old School Children: II - Affective." Research in Science and Technological Education, 2(2): 87-106, 1984.

261. Sneider, C. et. al. "Learning to Control Variables With Model Rockets: A Neo-Piagetian Study of Learning in Field Settings." Science Education, 68(4): 465-486, 1984.

262. Solarte Leon, J. I. "Analysis of an Earth Science Topic for Understanding Levels of Demand." Dissertation Abstracts International, 44(7): 2108-A, 1984.

263. Solomon, J. "Messy, Contradictory and Obstinately Persistent: A Study of Children's Out-of-School Ideas About Energy." School Science Review, 65(231): 225-229, 1983.

264. Sousa, D. "Recent Trends in Secondary Science Education in New Jersey." Journal of Research in Science Teaching, 21(3): 269-276, 1984.

265. Spear, M. G. "The Biasing Influence of Pupil Sex in a Science Marking Exercise." Research in Science and Technological Education, 2(1): 55-60, 1984.

266. Spector, B. S. "Qualitative Research: Data Analysis Framework Generating Grounded Theory Applicable to the Crisis in Science Education." Journal of Research in Science Teaching, 21(5): 459-467, 1984.

267. Spector, B. S. "Case Study of an Innovation Requiring Teachers to Change Roles." Journal of Research in Science Teaching, 21(6): 563-574, 1984.

268. Spickler, T. R. "An Experiment on the Efficacy of Intuition Development in Improving Higher Levels of Learning and Reasoning in Physical Science." Dissertation Abstracts International, 45(1): 143-A, 1984

269. Spraggins, C. C. "A Comparative Study of the Effect of Simulation Games and Worksheets as Teaching Strategies on Immediate Cognitive Learning and Retention of Varying Ability Groups in a High School Biology Classroom." Dissertation Abstracts International, 45(2): 483-A, 1984.

270. Srivastava, D. M. "The Savings Transfer Effect of Teaching Mathematical Modeling on Learning a Physics Unit Using a Mastery Learning Approach." Dissertation Abstracts International, 44(11): 3313-A, 1984.

271. Stankiewicz, J. J. "The Effects of an Advance Organizer on the Ability of Randomly Selected Groups of Seventh and Eighth Grade Science Students to Recall, and Apply Facts After a Visit to a Science Museum." Dissertation Abstracts International, 45(1): 143-A, 1984.

272. Staver, J. R. and E. T. Pascarella. "The Effect of Method and Format on the Responses of Subjects to a Piagetian Reasoning Problem." Journal of Research in Science Teaching, 21(3): 305-314, 1984.

273. Staver, J. R. "Effects of Method and Format on Subjects' Responses to a Control of Variables Reasoning Problem." Journal of Research in Science Teaching, 21(5): 517-526, 1984.

274. Steidley, C. W. "An Empirical Determination of Instructional Objectives Relating to the Computer in the College-Level General Physics Sequence." Dissertation Abstracts International, 44(11): 3274-A, 1984.

275. Stone, C. B. L. "From Forests to Fields to Food Webs: The Environment in History and Biology Textbooks, 1905-1975." Dissertation Abstracts International, 45(6): 1665-A, 1984.

276. Strawitz, R. M. "Cognitive Style and the Effects of Two Instructional Treatments on the Acquisition and Transfer to the Abiliy to Control Variables: A Longitudinal Study." Journal of Research in Science Teaching, 21(8): 833-841, 1984.

277. Strawitz, B. M. "Cognitive Style and the Acquisition and Transfer of the Ability to Control Variables." Journal of Reseach in Science Teaching, 21(2): 133-141, 1984.

278. Stuessy, C. S. L. "Correlates of Scientific Reasoning in Adolescents: Experience, Locus of Control, Age, Field Dependence-Independence, Rigidity/Flexibility, IQ, and Gender." Dissertation Abstracts International, 45(6): 1708-A, 1984.

279. Swift, J. N. et. al. "Observed Changes in Classroom Behavior Utilizing Supportive Intervention." Paper presented at the Annual Meeting of the National Association for Research in Science Teaching, New Orleans, LA, April, 1984. ED 245 891

280. Taglieber, J. E. "An Assessment of Science Achievement and Factors Related to Learning Outcomes of Eighth Grade Students in Santa Catarina (Brazil) State Schools." Dissertation Abstracts International, 44(8): 2431-A, 1984.

281. Talton, E. L. "Relationships of Attitudes Toward Classroom Environment With Attitudes Toward Science and Achievement in Science Among Tenth Grade Biology Students." Dissertation Abstracts International, 44(8): 2431-A, 1984.

282. Technical Education Research Center. Science and Mathematics Software Opportunities and Needs. Executive Summary. Cambridge, MA, June, 1983. ED 241 320

283. Templin, J. M. "Discovering a Classroom Strategy for Teaching Reading in the Content Area of Human Heredity and Development: The Relationship Between Reading Level, Attitude, and Application-Level Achievement." Dissertation Abstracts International, 45(3): 801-A, 1984.

284. Tessmer, M. A. "Learning Definitions Through Concept Trees." Dissertation Abstracts International, 44(11): 3366-A, 1984.

285. Teters, P. et. al. "What Research Says: Elementary Teachers' Perspectives on Improving Science Education." Science and Children, 22(3): 41-43, 1984.

286. Texley, J. T. and J. Norman. "The Development of a Group Test of Formal Operational Logic in the Content Area of Environmental Science." Journal of Research in Science Teaching, 21(6): 589-597, 1984.

287. Thomas, W. E. and D. A. Grouws. "Inducing Cognitive Growth in Concrete-Operational College Students." School Science and Mathematics, 84(3): 233-243, 1984.

288. Thong, B. "Planning and Implementing Interdisciplinary Studies Programs." Dissertation Abstracts International, 45(2): 404-A, 1984.

289. Tobin, K. "Student Task Involvement in Activity Oriented Science." Journal of Research in Science Teaching, 21(5): 469-482, 1985.

290. Tobin, K. "Effects of Extended Wait Time on Discourse Characteristics and Achievement in Middle School Grades." Journal of Research in Science Teaching, 21(8): 779-791, 1984.

291. Tobin, K. and W. Capie. "The Test of Logical Thinking." Journal of Science and Mathematics Education in Southeast Asia, 7(1): 5-9, 1984.

292. Trowbridge, D. and R. Durnin. Results from an Investigation of Groups Working at the Computer. Unpublished Research Report. University of California, Irvine. 1983. ED 238 724

293. Ulmer, D. C. "Implementing Energy Education Focusing on Attitudes and Concerns." Dissertation Abstracts International, 44(8): 2348-A, 1984.

294. Urevbu, A. O. "Teaching Concepts of Energy to Nigerian Children in the 7-11 Year-Old Range." Journal of Research in Science Teaching, 21(3): 255-267, 1984.

295. Vazquez, C. L. "The Effects of Computer Assisted Instruction in Chemistry Science Achievement at the Secondary School Level." Dissertation Abstracts International, 44(9): 2673-A, 1984.

296. Verkerk, G. "Practical Work in Dutch School Physics Examinations." Physics Education, 19(5): 229-232, 1984.

297. Wagner, A. M. "A Study of Elementary Science Achievement Related to Teacher Questioning Styles and Method of Instruction." Dissertation Abstracts International, 45(5): 1291-A, 1984.

298. Walker, A. J. "A Comparison Between the Inductive Guided-Discovery and the Deductive Exposition Methods of Teaching Science in an Elementary Classroom to Sixth Grade Students with Varying Cognitive Styles." Dissertation Abstracts International, 44(7): 2032-A, 1984.

299. Walkosz, M. and R. H. Yeany. "Effects of Lab Instruction Emphasizing Process Skills on Achievement of College Students Having Different Cognitive Development Levels." Paper presented at the Annual Meeting of the National Association for Research in Science Teaching, New Orleans, LA, April, 1984. ED 244 805

300. Warren, G. "Advanced Placement Biology as a Beginning Course." American Biology Teacher, 6(2): 109-112, 1984.

301. Watson, W. C. "A Study of the Piagetian Cognitive Development of Science and Humanities College Students From the Freshman to the Senior Year." Dissertation Abstracts International, 45(2): 484-A, 1984.

302. Waugh, M. L. "The Effects of Microcomputer-Administered Diagnostic Testing of the Short and Long Term Achievement of High School Biology Students of Varying Levels of Academic Aptitude and Achievement Motivation." Dissertation Abstracts International, 44(8): 2432-A, 1984.

303. Welch, W. W. et. al. "Women in Science: Perceptions of Secondary School Students." Paper presented at the Annual Meeting of the National Association for Research in Science Teaching, New Orleans, LA, April, 1984. ED 248 112

304. Wesley, B. E. "The Effects of Computer-Assisted Instruction and Locus of Control Upon Preservice Elementary Teachers' Aquisition of Computer Literacy and the Integrated Science Process Skills." Dissertation Abstracts International, 44(12): 3652-A, 1984.

305. Westerback, M. E. "Studies on Anxiety About Teaching Science in Preservice Elementary Teachers." Journal of Research in Science Teaching, 21(9): 937-950, 1984.

306. Westerback, M. E., C. Gonzales and L. H. Primavera. "Comparison of Anxiety Levels of Students in Introductory Earth Science and Geology Courses." Journal of Research in Science Teaching, 21(9): 913-929, 1984.

307. While, M. L. "An Impact Assessment of Participation in a National Science Foundation Human Genetics and Bioethical Decision-Making Workshop on Biology Teachers' Implementation of Project Synthesis Goals. Dissertation Abstracts International, 45(5): 1359-A, 1984.

308. Wiley, D. A. "A Comparison of the Effectiveness of Geological Conceptual Development Within Two Field Trip Types as Compared With Classroom Instruction." Dissertation Abstracts International, 45(1): 143-A, 1984.

309. Willson, V. L. "Adding Results to a Meta-Analysis: Theory and Example." Journal of Research in Science Teaching, 21(5): 527-535, 1984.

310. Wilson, A. H. and J. M. Wilson. "The Development of Formal Thought During Pretertiary Science Courses in Papua New Guinea." Journal of Research in Science Teaching, 21(5), 527-535, 1984.

311. Wilson, A. and J. M. Wilson. "The Development of Formal Thought Among High School Students in Papua New Guinea." Journal of Science and Mathematics Education in Southeast Asia, 7(1): 15-19, 1984.

312. Wise, K. C. "The Impact of Microcomputer Simulations on the Achievement and Attitude of High School Physical Science Students." Dissertation Abstracts International, 44(8): 2431-A, 1984.

313. Wittig, M. A., S. H. Sasse and J. Giacomi. "Predictive Validity of Five Cognitive Skills Tests Among Women Receiving Engineering Training." Journal of Research in Science Teaching, 21(5): 537-546, 1984.

314. Wolfe, L. F. "Toward Understanding the Ideas About Science Communicated by Elementary School Teachers." Dissertation Abstracts International, 44(9): 2673-A, 1984.

315. Wollman, W. "Models and Procedures: Teaching for Transfer of Pendulum Knowledge." Journal of Research in Science Teaching, 21(4): 399-415, 1984.

316. Wollman, W. and F. Lawrenz. "Identifying Potential Dropouts From College Physics Classes." Journal of Research in Science Teaching, 21(4): 385-390, 1984.

317. Woodward, A. and D. L. Elliot. "Evolution, Creationism, and Textbooks: A Study of Publishers' Perceptions of Their Markets." Paper presented at the Annual Meeting of the American Educational Research Association, New Orleans, LA, April, 1984. ED 245 940

318. Work, J. A. "The Relationship of Early Adolescent Learning Characteristics to Problem Solving." Dissertation Abstracts International, 45(6): 1708-A, 1984.

319. Wright, D. S. "Explicity Structured Physics Instruction." Dissertation Abstracts International, 45(4): 1089-A, 1984.

320. Wright, J. D. and D. L. Spiegel. "How Important is Textbook Readability to Biology Teachers?" American Biology Teacher, 46(4): 221-225, 1984.

321. Yager, R. E. and R. J. Bonnstetter. "Student Perceptions of Science Teachers, Classes, and Course Content." School Science and Mathematics, 84(5): 406-414, 1984.

322. Yarroch, W. L. "Teacher Instruction and Student Performance in Balancing Chemical Equations: An Observational Report." Dissertation Abstracts International, 44(9): 2674-A, 1984.

323. Yeany, R. H. "Analyzing Hierarchical Relationships Among Modes of Cognitive Reasoning and Integrated Science Process Skills." Paper presented at the Annual Meeting of the National Association for Research in Science Teaching, New Orleans, LA, April, 1984. ED 244 803

324. Yore, L. D. "The Effects of Cognitive Development and Age on Elementary Students Science Achievement for Structured Inductive and Semi-Deductive Inquiry Strategies." Journal of Research in Science Teaching, 21(7): 745-753, 1984.

325. Zeidler, D. L. and L. E. Schafer. "Identifying Mediating Factors of Moral Reasoning in Science Education." Journal of Research in Science Teaching, 21(1): 1-15, 1984.

326. Zeidler, D. L. "Patterns of Hierarchy in Formal and Principled Moral Reasoning." Paper presented at the Annual Meeting of the National Association for Research in Science Teaching, New Orleans, LA, April, 1984. ED 243 700

327. Zeitler, W. R. "Science Backgrounds, Conceptions of Purposes, and Concerns of Preservice Teachers About Teaching Children Science." Science Education, 68(4): 505-520, 1984.

328. Zeitoun, H. H. "Teaching Scientific Analogies: A Proposed Model." Research in Science and Technological Education, 2(2): 107-125, 1984.

329. Zitzewitz, B. S. "A Study of Learning From Microcomputer Programs in College General Chemistry." Dissertation Abstracts International, 44(10): 3027-A, 1984.

Additional References

Abdi, Ahmed Ali. "Revision of Primary I-III Science Curriculum in Somalia." African Studies in Curriculum Development and Evaluation. Nairobi, Kenya: Institute of Education, 1983. ED 248 117

Al-Hussain, Abdullah Ali. "An Analysis of the Science Curriculum in Public Secondary Schools in Saudi Arabia as Perceived by Saudi Science Students in the United States." Dissertation Abstracts International, 44(7): 2107-A, 1984.

Al-Rasheed, Abdullah Ahmad. "An Investigation of the General Affective Behavior Toward Science Held by Secondary School Scientific Section Students at Riyadh City, Saudi Arabia." Dissertation Abstracts International, 45(1): 142-A, 1984.

Atchia, Michael, Ed. "Research in Community-Based Biological Education." 4 Case-Studies, Reduit, Mauritius: Mauritius Institute of Education, June, 1982. ED 247 125

Bindocci, Cynthia Gay Mason. "Identification of Technology Content for Science and Technology Centers." Dissertation Abstracts International, 44(7): 2024-A, 1984.

Buescher, Georganne Kretschman. "Identificatin of That Science and Mathematics Content Needed by Medical Technologists as Perceived by Baccalaureate Program Directors, Directors of Clinical Laboratories, and Medical Technologists." Dissertation Abstracts International, 45(1): 66-A, 1984.

Cooper, Colin. "Discriminant Factors in the Choice of a Traditional "People-Oriented" Versus a Non-Traditional 'Math and Science-Oriented' Career Field in Black Students." Dissertation Abstracts International, 45(5): 1611-B, 1984.

Flagg, Thomas John. "Articulation in the Biological and Physical Sciences Between the University of Central Florida and Valencia Community College." Dissertation Abstracts International, 45(3): 800-A, 1984.

Harris, Willie Davis. "Secondary School Science Teaching, 1918-1972: Objectives as Stated in Periodical Literature." Dissertation Abstracts International, 45(3): 802-A, 1984.

Kahuki, Isaiah Njau. "Evaluation of Three Course Patterns for the Implementation of Science Laboratory Technician Curriculum in Applied Sciences." African Studies in Curriculum Development and Evaluation. Nairobi, Kenya: Institute of Education, 1984. SE044772.

Kramer, Beryl Marjorie Cayzer. "Study of the Relationship Between Safety Knowledge and Student Perception of Safety Practices of Secondary School Science Teachers." Dissertation Abstracts International, 45(5): 1358-A, 1984.

Madrazo, Gerardo, Jr. "A Study of the Role Expectancy of the Science Supervisor in North Carolina as Perceived by Administrators Teachers, College Science Educators and Supervisors Themselves." Dissertation Abstracts International, 45(4): 1024-A, 1984.

Myers, Edwin C.; Mineo, R. James. "Mathematics and Science Instruction in Southern California." Los Alamitos, CA. October, 1983. ED 249 085

Nash, Melanie; and Others. "Factors Affecting Pupil Uptake of Technology at 14+." Research in Science and Technological Education, 2: 5-19, 1984.

Nentwig, Peter; And Others. "Doktorgrade in Naturwissenschaftsdidaktik: Voraussetzungen and Forschungesbereiche fur Dissertationen = Doctorates in Science Education: Prerequisites and Research Areas for Dissertations." IPN Report in Brief, Eighth Edition: Kiel, West Germany, 1983. ED 244 784

Ochola, Joel Aduma. "Investigating the Relevance of Some Suggested Textbooks for Teaching of the New Chemistry Syllabus in Kenyan Secondary Schools." African Studies in Curriculum Development and Evaluation. Nairobi, Kenya: Institute of Education, 1983. ED 248 116

Otewa, John Odhiambo. "The Factors Affecting the Teaching of Biology in Both Government and Harambee Secondary Schools in Kenya." African Studies in Curriculum Development and Evaluation. Nairobi, Kenya: Institute of Education, 1983. ED 248 119

Pham, Rex Thien-Hung. "A Two-Paradigm Science Exploration of Science Issues, Journalism, and Q Methodology." Dissertation Abstracts International, 45(2): 331-A, 1984.

Roquemore, Leroy. "An Examination of the Effects of Computer-Assisted Instruction on the Quality of Instruction in Selected Science Courses at a Developing Institution." Dissertation Abstracts International, 45(6): 1840-B, 1984.

"Science for Every Student: Educating Candians for Tomorrow's World." Report 36, Ontario, Canada: April, 1984. ED 247 086

Skraly, Janice Ann. "Creativity and its Relationship to Science Ability: An Analysis of Gifted and Non-Gifted Program Membership." Dissertation Abstracts International, 44(8): 2434-A, 1984.

Squiccimarro, Anne Rice. "Personalizing Science Teaching Through Student Journal-Keeping." Dissertation Abstracts International, 45(4): 1088-A, 1984.

Walugere, Richard. "The Effectiveness of Radio Programmes as a Strategy for Teaching Science in Primary Schools in Uganda." African Studies in Curriculum Development and Evaluation. Nairobi, Kenya: Institute of Education, 1983. ED 248 118

Wier, Elizabeth Avery. "A Study on the Use of Supplemental Reading With A Middle School Science/Social Studies Curriculum to Promote Voluntary Reading and Provide for Individual Differences." Dissertation Abstracts International, 45(6): 1634-A, 1984.